Comptes Rendus N° 11

CONSEIL INTERNATIONAL DES UNIONS SCIENTIFIQUES

UNION GÉODÉSIQUE ET GÉOPHYSIQUE INTERNATIONALE

ASSOCIATION DE SÉISMOLOGIE ET DE PHYSIQUE DE L'INTÉRIEUR DE LA TERRE

COMPTES RENDUS DES SÉANCES DE LA DIXIÈME CONFÉRENCE

RÉUNIE A ROME DU 14 AU 25 SEPTEMBRE 1954

Rédigés par le Secrétaire J. P. ROTHÉ

Publié avec le concours financier de l'UNESCO

Société Nouvelle d'Impression
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UNION GÉODÉSIQUE ET GÉOPHYSIQUE INTERNATIONALE

ASSOCIATION INTERNATIONALE DE SÉISMOLOGIE ET DE PHYSIQUE DE L'INTÉRIEUR DE LA TERRE

BUREAU et COMMISSIONS.

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PRÉSIDENT :

Prof. *K. E. Bullen*, F.R.S., University of Sydney, Department of Applied Mathematics, Sydney, N.S.W. (Australia).

VICE-PRÉSIDENTS :

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Dr *E. Wanner*, Chef du Service séismologique suisse, Station Centrale Suisse de Météorologie, Krähbühlstrasse 58, Zürich 7/44 (Suisse).

SECRÉTAIRE GÉNÉRAL :

Prof. *J.-P. Rothé*, Institut de Physique du Globe, 38, boulevard d'Anvers, Strasbourg (France).

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MM. Prof. *Beno Gutenberg*, Seismological Laboratory, 220, N. San Rafael Avenue, Pasadena 2 (California) U.S.A.

Dr *Markus Bath*, Meteorological Institute, Uppsala (Sweden).

Prof. Ing. *Simon Gershanik*, Jefe de Departamento de Geofisica, Instituto Superior del Observatorio Astronomico, La Plata (Argentine).

Dr *J. H. Hodgson,* Dominion Observatory, Department of Mines and Technical Surveys, Ottawa (Canada).

Rev. Dr *R. Ingram,* Rathfarnham Castle, Rathfarnham, (Co. Dublin) (Ireland).

COMMITTEE
FOR THE INTERNATIONAL SEISMOLOGICAL SUMMARY

CHAIRMAN :

Sir *Harold Jeffreys,* F.R.S., Professor at St. John's College, Cambridge (Grande-Bretagne).

MEMBERS :

Mlle *I. Lehmann,* Kastelsvej 26, Copenhague (Danemark).

MM. Prof. *Beno Gutenberg,* Seismological Laboratory, 220 N. San Rafael Avenue, Pasadena 2 (California), U.S.A.

Dr *J. H. Hodgson,* Dominion Observatory, Department of Mines and Technical Surveys. Ottawa (Canada).

Rev. Dr *J.-B. Macelwane,* Institute of Technology, St. Louis University, 3621 Olive Street, St. Louis, 8 (Missouri) U.S.A.

Dr *R. Stoneley,* F.R.S., 16 Millington Road, Cambridge (Grande-Bretagne).

Dr *E. Vesanen,* Tunturikatu 14 B, Helsinki (Finland).

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RAPPORTEURS :

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Prof. Dr *Vening-Meinesz,* Potgieterlaan 5, Amersfoort (Pays-Bas).

Interprétations gravimétriques :

Prof. Jean Goguel, 100, rue du Bac, Paris (7e).

Radioactivité et Géothermie :

Sir *Edward Bullard,* F.R.S., Department of Geodesy and Geophysics, Madingley Rise, Madingley Road, Cambridge (Grande-Bretagne).

Prof. *J. T. Wilson,* Department of Physics, University of Toronto (Ontario), Canada.

Elasticité et Plasticité :

Sir *Harold Jeffreys,* F.R.S., Professor at St. John's College, Cambridge (Grande-Bretagne).

Dr *R. Stoneley,* F.R.S., 16 Millington Road, Cambridge (Grande Bretagne).

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PRÉSIDENT :

Prof. Dr. *W. Hiller,* Württ. Erdbebendienst, Stuttgart-O., Richard-Wagner-Strasse 15 (Allemagne).

SECRÉTAIRE :

Prof. *Pietro Caloi,* Istituto Nazionale di Geofisica, Citta Universitaria, Rome (Italie).

MEMBRES :

MM. Prof. Dr *M. Bath,* Meteorological Institute, Uppsala (Suède).

Prof. D.*Juan Bonelli Rubio,* Jefe del Servicio Nacional de Sismologia del Instituto Geografico y Catastral, Calle General Ibañez Ibero N° 3, Madrid (Espagne).

M. *J. Debrach,* Service de Physique du Globe et de Météorologie de l'Institut Scientifique Chérifien, 2, rue de Foucauld, Casablanca (Maroc).

Prof. Dr *H. A. Ferreira,* Serviço Meteorológico Nacional, Largo de Santa Isabel, Lisbonne (Portugal).

Prof. Dr *A. Galanopoulos,* Université d'Athènes, Chef de la Section Géodynamique, Observatoire National, 4, rue Massalias, Athènes (Grèce).

Dr *J. M. Van Gils,* Institut Royal Météorologique de Belgique, Service séismologique, 3, avenue Circulaire, Uccle (Belgique).

Prof. Dr *G. Grenet,* Directeur de l'Institut de Météorologie et de Physique du Globe de l'Algérie, Université, Alger (Algérie).

Rev. Dr *R. Ingram,* Rathfarnham Castle, Rathfarnham, (Co. Dublin) (Ireland).

Dr *A. Kvale,* Director, Earthquake Station, Universitetet i Bergen, Jordskjelvstasjonen, Joach. Frieles gt. 1 II, Bergen Norvège).

Mlle *I. Lehmann,* Kastelsvej 26, Copenhague (Danemark).

MM. Prof. Dr *J. Mihailovic,* Directeur de l'Institut séismologique de Beograd (Yougoslavie).

E. Peterschmitt, Institut de Physique du Globe de Strasbourg, 38, boulevard d'Anvers, Strasbourg (France).

Mlle Dr *Nuriye Pinar,* Izmir Mebusu, Ankara (Turquie).

MM. Dr *J. C. Scholte,* v. Alphenstraat 12, Utrecht (Pays-Bas).

Dr *E. Tillotson,* The Homestead, Menston-in-Wharfedale, (Yorkshire), Grande Bretagne.

Prof. Dr *M. Toperczer,* Leiter der Geophysikalischen Abteilung an der Zentralanstalt für Meteorologie und Geodynamik, Hohe Warte, Wien XIX (Autriche).

Dr *E. Tryggvason,* Vedurstofan, Reykjavik (Islande).

Prof. Dr *E. Vesanen,* Tunturikatu 14 B, Helsinki (Finlande).

Dr *E. Wanner,* Chef du Service séismologique suisse, Station Centrale Suisse de Météorologie, Krähbühlstrasse 58, Zürich 7/44 (Suisse).

ASSEMBLÉE GÉNÉRALE DE ROME

(14 au 25 septembre 1955)

HORAIRE DES SÉANCES

MARDI, 14 SEPTEMBRE

10 h. 30 : Séance inaugurale et Première Séance plénière de l'U.G.G.I.

15 h. 00 : Association de Séismologie : Adresse présidentielle du Professeur Gutenberg.

MERCREDI, 15 SEPTEMBRE

9 h. 00 : Première séance de travail : Rapports du Secrétaire Général et du Président de la Commission de l'I.S.S ; discussion sur l'I.S.S.

15 h. 00 : Deuxième séance de travail : Graphiques de durées de propagation, dictionnaire séismologique, catalogue des stations séismologiques mondiales, direction de l'I.S.S.

JEUDI, 16 SEPTEMBRE

9 h. 00 : Troisième séance de travail : Distribution des Rapports Nationaux; année géophysique internationale; élection du nouveau Bureau; rapport de la Commission des Finances.

14 h. 00 : Quatrième séance de travail : Communications scientifiques : Mesures séismiques; magnitude.

VENDREDI, 17 SEPTEMBRE

9 h. 00 : Cinquième séance de travail : Communications scientifiques : Ondes séismiques.

14 h. 00 : Sixième séance de travail (séance commune avec l'Association d'Hydrologie, section neige et glaciers) : Etude sur l'Inlandsis du Groenland.

14 h. 45 : Communications scientifiques : Ondes séismiques (suite).

SAMEDI, 18 SEPTEMBRE

9 h. 00 : Septième séance de travail : Communications scientifiques: Ondes séismiques (suite).

LUNDI, 20 SEPTEMBRE

9 h. 00 : Huitième séance de travail (séance commune avec l'Association de Volcanologie) : Rapport sur l'Age de la Terre; communications scientifiques : Radioactivité.

9 h. 00 : Neuvième séance de travail: Communications scientifiques: Appareillage séismique.

11 h. 15 : Visite de la Station séismologique de Rome.

14 h. 00 : Dixième séance de travail (séance commune avec l'Association Internationale de Magnétisme) : Movements in the Earth's core and Electrical Conductivity.

MARDI, 21 SEPTEMBRE

9 h. 00 : Onzième séance de travail (séance commune avec l'Association de Volcanologie) : Communications scientifiques : Constitution de la Terre; dissipation de l'énergie dans la terre.

14 h. 00 : Douzième séance de travail (séance commune avec les Associations de Géodésie et de Volcanologie) : Rapport sur l'Isostasie; communications scientifiques : Déformations actuelles; isostasie.

14 h. 30 : Treizième séance de travail: Communications scientifiques: Radioactivité.

MERCREDI, 22 SEPTEMBRE

9 h. 00 : Quatorzième séance de travail : Communications scientifiques : Géothermie.

9 h. 00 : Quinzième séance de travail : Communications scientifiques : Microséismes.

14 h. 15 : Seizième séance de travail (séance commune avec l'Assosiation de Géodésie) : Communications scientifiques : Interprétations gravimétriques et séismiques.

JEUDI, 23 SEPTEMBRE

9 h. 00 : Dix-septième séance de travail : Communications scientifiques : Géographie séismologique.

14 h. 00 : Dix-huitième séance de travail : Communications scientifiques : Divers; clôture de l'Assemblée de l'Association.

SAMEDI, 25 SEPTEMBRE

10 h. 00 : Assemblée plénière de clôture de l'U.G.G.I.

LISTE DES PARTICIPANTS AUX SÉANCES DE L'ASSOCIATION

(15 au 23 septembre 1954)

(Liste établie d'après les signatures portées sur les feuilles de présence)

Les numéros indiquent les séances auxquelles ont assisté les délégués dont les noms suivent :

Séance 1 15 septembre matin
2 15 septembre après-midi
3 16 septembre matin
4 16 septembre après-midi
5 17 septembre matin
6 17 septembre après-midi
7 18 septembre matin
8 20 septembre matin (Radioactivité)
9 20 septembre matin (Appareillage séismique)
10 20 septembre après-midi
11 21 septembre matin
12 21 septembre après-midi (Déformations; isostasie)
13 21 septembre après-midi (Radioactivité)
14 22 septembre matin (Géothermie)
15 22 septembre matin (Microséismes)
16 22 septembre après-midi (Interprétations gravimétriques et séismiques)
17 23 septembre matin
18 23 septembre après-midi.

MM.	Adkins (U.S.A.) :	4, 6, 14, 16, 18.
	Antunes (Portugal) :	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 16, 17, 18.
	Ardan (Turquie) :	6.
	Argentieri (Italie) :	16.
	Atherton (Gr. Bretagne)) :	10, 16.
	Baetsle (Belgique) :	12.
	Ballarin (Italie) :	12.
	Balsley (U.S.A.) :	14, 16.
	Baranov (France) :	5, 7, 16.
	Barrabé (France) :	8, 11, 12, 14.
	Bath (Suède) :	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 15, 16, 17, 18.
	Bauer (France) :	16.
	Baxter (Gr. Bretagne) :	1, 2, 3, 4, 5, 6, 7, 9, 11, 15, 18.

Beals (Canada) : 7, 10, 16, 18.
Beers (U.S.A.) : 4, 7, 8, 10.
Begeman (Suisse) : 13.
Beloussov (U.R.S.S.) : 10, 12, 16.
Benioff (U.S.A.) : 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 16, 17, 18.
Ben Osman (Tunisie) : 1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 15, 16, 17.
Berlage (Pays-Bas) : 12, 14.
Birch (U.S.A.) : 4, 5, 8, 10, 12, 13, 14, 16.
Boato (Italie) : 8, 13.
Bobrovnikoff (U.S.A.) : 10, 16.
Bollo (France) : 5, 12, 16.
Bonelli (Espagne) : 1, 2, 3, 4, 5, 6, 9, 15, 16, 17, 18.
Bossolasco (Italie) : 11, 15.
Bourgeois (Belgique) : 9.
Bremaecker de (C. Belge) : 1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 14, 16, 17.
Brockamp (Allemagne) : 4, 5, 6, 8, 9, 11, 14, 16.
Brown (U.S.A.) : 4, 8, 10, 13.
Browne B. C. (Gr. Bret.) : 4, 12, 16.
Bucher (U.S.A.) : 4, 5, 6, 12, 14, 16.
Bullard (Gr. Bretagne) : 4, 8, 10, 11, 13, 14, 18.
Bullen (Australie) : 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 14, 16.
Bullerwell (Gr. Bretagne) : 12, 16.
Caloi (Italie) : 1, 5, 7, 11, 12, 17, 18.
Carder (U.S.A.) : 1, 2, 3, 4, 5, 7, 11, 12, 15, 16, 17.
Cassinis (Italie) : 16.
Castany (Tunisie) : 2, 14.
Cattaneo (Italie) : 3, 5, 8.
Clark : 18.
Closs (Allemagne) : 4, 11, 13, 16.
Colledan (Italie) : 11.
Cook (Gr. Bretagne) : 16.
Cooper (Gr. Bretagne) : 8.
Coppede (Italie) : 17.
Coron (France) : 12, 16.
Cortesi (Italie) : 8, 9.
Coulomb (France) : 10, 15.
Cunietti (Italie) : 12, 16.
Day (Gr. Bretagne) : 4, 5, 6, 7, 8, 10, 16.
Deacon (Gr. Bretagne) : 15.
Debrach (Maroc)) : 1, 2, 3, 5, 7, 12, 15, 16, 17.
De Graaff-Hunter (Gr. Bretagne) : 16.
De Panfilis (Italie) : 1, 7, 17.
Deutsch (Gr. Bretagne) : 12, 16.
Dietz (Gr. Bretagne) : 4, 8, 10.
Di Filippo (Italie)) : 5, 7.
Dilgan (Turquie) : 2, 3, 4, 6, 7, 9, 11, 12, 15, 16, 17, 18
Du Bois (Gr. Bretagne) : 10, 16.
Mme Duclaux (Algérie) : 9, 10.

MM.	Dürbaum (Allemagne) :	4, 8, 12, 16.
	Emery (U.S.A.) :	8.
	Errulat (Allemagne) :	7, 11.
	Etienne (Haïti) :	12.
	Ewing (U.S.A.) :	3, 4, 5, 6, 7, 8, 10, 11, 12, 14, 16, 17.
	Farquhar (Canada) :	4, 8, 10, 11, 13, 14.
	Faul (U.S.A.) :	8, 13.
	Fedorov (U.R.S.S.) :	16.
Mlle	Festa (Italie) :	8, 13.
MM.	Galanopoulos (Grèce) :	1, 2, 4, 5, 6, 7, 9, 11.
	Gaskell (Gr. Bretagne) :	4, 5, 6, 7, 10, 11, 16.
	Gassmann (Suisse) :	4, 5, 6, 7, 11, 12, 14, 16.
	Geiss (Suisse)) :	13.
	Geneslay (France) :	1, 2, 3, 4, 5, 7, 8, 10, 14, 16 17.
	George (U.S.A.) :	12.
	Gevers (Afrique du Sud) :	8, 10, 12, 14, 16.
	Giorgi (Italie) :	15.
	Girlanda (Italie) :	1, 5, 7, 9, 11, 12, 15, 16, 17, 18.
	Glangeaud (France) :	8, 14, 17.
	Glennie (Gr. Bretagne) :	12, 16.
	Goguel (France) :	8, 11, 12, 14, 16.
	Gonçalves (Portugal) :	12.
	Gorshkov (U.R.S.S.) :	6, 17.
Mlle	Grandjean (Algérie) :	1, 2, 3, 4, 5, 6, 7, 9, 11, 15, 17.
MM.	Grenet (Algérie) :	5, 6, 9, 11, 15, 17.
	Griffiths (Gr. Bretagne) :	10, 12, 14, 16.
	Grossmann (Allemagne) :	12.
	Gulatee (Inde) :	8, 12.
	Gutenberg (U.S.A.) :	1, 2, 3. 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 16, 17, 18.
	Guyot (Suisse) :	1, 2, 5, 7.
	Härmälä (Finlande) :	12.
	Hagiwara (Turquie) :	4, 5, 7, 12, 16, 17, 18.
	Hales (Afrique du Sud) :	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 14, 16, 18.
	Hall (Gr. Bretagne) :	3, 4, 5, 7, 8, 10, 11, 18.
	Hardtwig (Allemagne) :	3, 4, 5, 7, 9, 10, 11, 12, 15, 17.
Mme	Hée (France) :	8, 10, 13, 14.
MM.	Heinrich (U.S.A.) :	1, 2, 3, 5, 7, 9, 11, 15, 18.
	Heiskanen (Finlande) :	12, 16.
	Hide (U.S.A.) :	6.
	Hill (Gr. Bretagne) :	1, 4, 5, 6, 7, 8, 10, 14.
	Hiller (Allemagne) :	1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 15, 17, 18.
	Hodgson (Canada) :	1, 2, 3, 4, 5, 7, 10, 11, 12, 16, 18.
	Hoinkes (Autriche) :	14.
	Holtzscherer (France) :	2, 3, 4, 5, 6, 9, 11, 12, 14, 15, 16.
	Hoskinson (U.S.A.) :	12, 16.
	Hough (U.S.A.) :	16.
	Houtermans (Suisse) :	8, 10, 13.
	Hughes (Gr. Bretagne) :	1, 2, 3, 4, 5, 6, 7, 9.

Imbert (France) : 4, 5.
Imbo (Italie) : 12.
Innes (Canada) : 12, 16, 18.
Ingram (Irlande) : 1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 15, 16, 17, 18.
Irving (Gr. Bretagne) : 4, 12, 14.
Jacobs (Canada) : 1, 2, 8, 11, 14.
Jaeger (Gr. Bretagne) : 4, 8, 10, 11, 12, 14, 16.
Jeffreys (Gr. Bretagne) : 1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 14.
Jensen (Danemark) : 1, 2, 3, 4, 5, 6, 7, 9, 12, 15, 16, 17, 18.
Mme Jérémine (France) : 11.
M. Jobert G. (France) : 4, 5, 6, 7, 9, 11, 12, 14, 16, 17, 18.
Mme Jobert N. (France) : 4, 5, 6, 7, 9, 11, 12, 14, 16, 17, 18.
MM. Jones (Belgique) : 12.
Jung K. (Allemagne) : 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 16, 18.
Jung J. G. (France) : 8, 14.
Kalaja (Finlande) : 16.
Kalashnikov (U.R.S.S.) : 12.
Keller (France) : 14.
Kenney (Gr. Bretagne) : 10, 16.
Ketin (Turquie) : 4, 5, 8, 12, 16, 17.
Koczy (Suède) : 4, 8, 10, 13.
Koebcke (Pologne) : 12.
Koridalin (U.R.S.S.) : 5.
Krumbach (Allemagne) : 5, 6, 7, 9, 11, 15, 16, 17.
Mme Labrouste (France) : 1, 2, 3, 4, 5, 6, 7, 9, 11, 15, 18.
MM. Lahn (Turquie) : 1, 4, 8, 10, 11, 14, 17, 18.
Lambert (U.S.A.) : 12, 16.
Lapwood (Gr. Bretagne) : 1, 2, 4, 5, 6, 7, 8, 11, 12, 14, 16, 17, 18.
Mlle Lehmann (Danemark) : 1, 3, 4, 5, 6, 7, 8, 10, 11, 14, 15, 18.
MM. Lejay (France) : 16.
Lewis (Gr. Bretagne) : 6.
Lichte (Allemagne) : 12.
Longuet-Higgins (Gr. Bret.) : 18.
Lowes (Gr. Bretagne) : 4, 10, 14.
Lozano (Espagne) : 16.
Lynch (U.S.A.) : 6, 11, 15.
Macelwane (U.S.A.) : 4, 6, 7.
McFarlane (Gr. Bretagne) : 4, 6, 10, 11, 12, 14, 16.
MacGregor (Gr. Bretagne) : 8, 10, 12, 14.
Marble (U.S.A.) : 8, 10, 13, 14.
Mlle Marcelli (Italie) : 1, 5, 7, 17.
MM. Martin (France) : 6.
Mason (Gr. Bretagne) : 8, 13, 14.
Maxwell (U.S.A.) : 1, 2, 4, 8, 11, 12, 14.
Medi (Italie) : 5.
Meisser (Allemagne) : 1, 2, 3, 4, 5, 6, 9, 11, 12, 14, 15, 16, 17, 18.
Menzel (Allemagne) : 1, 2, 3, 4, 5, 6, 7, 9, 11, 15, 16, 17, 18.

	Migaux (France) :	1, 2, 3, 5, 8.
	Minakami (Japon) :	12, 14, 15, 16.
	Mintrop (Allemagne) :	1, 6, 11, 12, 14.
	Misener (Canada) :	1, 4, 8, 11, 14.
	Mokrovic (Yougoslavie) :	1, 3, 4, 5, 6, 7, 9, 10, 11, 14, 15.
	Molodensky (U.R.S.S.) :	16.
	Moore (Gr. Bretagne) :	4, 10, 14.
	Morelli (Italie) :	12.
	Munck (U.S.A.) :	10, 14.
	Murphy (Irlande) :	6, 16.
	Nemiro (U.R.S.S.) :	16.
	Neumann van Padang (Pays-Bas) :	8, 10.
	Niblett (Gr. Bretagne) :	4, 10, 14.
	Nœtzlin (France) :	8, 10, 11, 13, 14.
	Parry (Gr. Bretagne) :	4, 10, 12, 16.
	Pekeris (Israel) :	4, 5, 6, 7, 10, 11, 14, 16.
	Peoples (U.S.A.) :	4, 5, 7, 11, 14, 16, 17.
	Pepper (U.S.A.) :	16.
	Perri (Italie) :	11.
	Peterschmitt (France) :	1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 15, 16, 17, 18.
	Pettersson (Suède) :	11, 13.
	Plassard (Liban) :	12, 16, 17.
	Picciotto (Belgique) :	8, 13, 14.
Mlle	Pinar (Turquie) :	17.
MM.	Press (U.S.A.)) :	4, 5, 6, 7, 9, 11, 12, 15, 16, 17, 18.
	Raitt (U.S.A.) :	16.
	Ramsey (Gr. Bretagne) :	3, 10, 14, 16.
	Ramachandra Rao (Inde) :	6, 10, 12, 14, 16.
	Revelle (U.S.A.) :	4, 8, 10, 14.
	Rice (U.S.A.) :	16.
	Richey (Gr. Bretagne) :	8, 10, 12, 14.
	Rieckmann (Allemagne) :	12.
	Rikitake (Gr. Bretagne) :	7, 10, 14, 15.
	Rittmann (Egypte) :	10, 14.
	Roberts (Gr. Bretagne) :	10, 14.
	Robertson (Gr. Bretagne) :	2, 5, 14, 16.
	Robin G. de (Gr. Bretagne) :	5, 6.
	Romana (Espagne) :	4, 7.
	Ronnstock (Australie) :	12.
	Rösch (France) :	2, 6, 13.
	Rosini (Italie) :	15.
	Rothé (France) :	1, 2, 3, 4, 5, 6, 7, 8, 11, 12, 14, 15, 16, 17, 18.
	Routhier (France) :	8, 14, 18.
	Ruffili (Ecuador) :	5, 7.
	Runcorn (U.S.A.) :	7, 10, 12.
	St. Amand (U.S.A.) :	18.
	Sanders (Belgique) :	12, 16.
	Sargin (Turquie) :	17.
	Scholte (Pays-Bas) :	3, 4, 6, 7, 10, 15, 18.

	Schumacher (Haïti) :	4, 5, 7, 9, 12, 17, 18.
	Shalem (Israel) :	17.
	Singer (U.S.A.) :	13.
	Slaucitajs (Argentine) :	1, 10.
	Slichter (U.S.A.) :	4, 5, 6, 8, 11, 13, 14, 16.
	Smith W. E. (U.S.A.) :	7, 8.
	Sousa Nazareth (Portugal) :	13.
Mlle	Spadea (Italie) :	5, 7, 11, 12, 18.
MM.	Stahl (France) :	12, 16.
	Stoneley (Gr. Bretagne) :	1, 2, 3, 4, 5, 6, 8, 10, 11, 13, 14, 17, 18.
	Tams (Allemagne) :	1, 2, 3, 4, 5, 6, 7, 11, 12, 17, 18.
	Tixeront (Tunisie) :	17.
	Tomaschek (Gr. Bretagne) :	3, 9, 10, 11, 12, 16.
	Toperczer (Autriche) :	5, 7, 9, 10, 11, 15, 16, 17.
	Tozer (Gr. Bretagne) :	4, 7, 14.
	Tryggvason (Islande) :	1, 4, 5, 6, 7, 9, 11, 12, 15, 16, 17, 18.
	Tsuboi (Japon) :	4, 7, 10, 11, 12, 16, 17 18.
	Uffen (Canada)) :	1, 2, 4, 12, 14.
	Untersteiner (Autriche) :	14, 16.
	Urey (U.S.A.) :	8, 10, 14.
	Vacquier (U.S.A.) :	10, 11, 14, 16.
	Valle (Italie) :	5, 7, 8, 11.
	Vecchia (Italie) :	1, 6, 10, 12, 16, 17, 18.
	Veldkamp (Pays-Bas) :	6.
	Vening-Meinesz (Pays-Bas) :	4, 12, 14, 16, 18.
	Verhoogen (U.S.A.) :	11, 13, 14.
	Vesanen (Finlande) :	1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 14, 15, 18.
	Vodusek (Yougoslavie) :	4, 9, 11.
	Wadati (Japon) :	2, 3, 4, 5, 6, 7, 9, 11, 12, 15, 16, 17, 18.
	Wanner (Suisse) :	1, 2, 3, 4, 6, 7, 9, 10.
	Walton (Gr. Bretagne) :	10, 11.
	Weelden A. van (Pays-Bas) :	4, 12, 16, 17.
	Welis H. W. (U.S.A.) :	8, 9, 16.
	Wilson C. D. V. (Gr. Bret.) :	3, 4, 5, 6, 7, 11, 12, 14, 16, 18.
	Wilson James T. (U.S.A.) :	4, 5, 6, 9, 11, 16, 18.
	Wilson J. Tuzo (Canada) :	1, 4, 8, 12, 16.
	Worzel (U.S.A.) :	4, 5, 6, 7, 8, 14, 16.
	Wiseman (Gr. Bretagne) :	8.
	Whitten (U.S.A.) :	16.
	Yarar (Turquie) :	6, 7, 9, 10, 11, 12, 15, 16, 17.
	Zverev (U.R.S.S.) :	16.

En outre ont également assisté à la 10e séance : MM. Ahrens, Ambolt, Ashour, Bartels, Berkner, Chapman, Curtis, Danusaputro, Davies, Egedal, Finch, Gold, Goody, Houghton, Jerlov, Kantas, Kunetz, Lahaye, Madill, Möller, Nelson, Neumann J., O'Connell, Olsen, Odishaw, Price, Rayner, Rivault, Mlle Roquet, MM. Sayar, Spencer Jones, Stoyko, Strong, Uzdilek, Von Glasenapp, Vlodavez, Worden, Yriberry.

ASSEMBLÉE GÉNÉRALE DE ROME

(14 au 25 septembre 1954)

COMPTES RENDUS DES SÉANCES

MARDI 14 SEPTEMBRE

Adresse présidentielle

A 15 h., en présence de très nombreux Membres de l'Association Internationale de Séismologie et de Physique de l'Intérieur de la Terre et de l'Association de Magnétisme terrestre le *Président Gutenberg* donne lecture de son Adresse présidentielle, intitulée : Effects of low-velocity layers.

Cette adresse est accompagnée de projections. Le texte complet de l'adresse présidentielle du *Président Gutenberg* est publié dans « *Geofisica Pura e Applicata* », Vol. 29, pp. 1-10, 1954.

PREMIÈRE SÉANCE

MERCREDI 15 SEPTEMBRE (matin)

Programme

1. — Nécrologie.
2. — Rapport du Secrétaire Général.
3. — Constitution d'une Commission des finances.
4. — Rapport du Président de la Commission de l'I.S.S.
5. — Discussion sur l'I.S.S.

La séance est ouverte à 9 h. 10 sous la présidence du *Professeur Gutenberg*.

M. *J. Cl. de Bremaecker* est désigné pour faire fonction de Secrétaire de langue anglaise et d'interprète pour la durée de l'Assemblée. (1)

1. Nécrologie

Le *Président Gutenberg* rend hommage aux séismologues disparus.

Le *Professeur Charles Charlier*, né à Schaerbeek le 15 mars 1897, nous a quittés le soir du 21 novembre 1953, jour anniversaire de son entrée à l'Observatoire Royal de Belgique, trente ans auparavant. Il s'est éteint après une longue et déprimante maladie, supportée avec courage et résignation, alors qu'il entrait à peine dans sa 57e année. Frappé par la mort en pleine maturité, il laisse en cours une série de travaux dont l'achèvement confirmera l'ampleur de vues dont il fit toujours preuve en sciences.

Entré en 1923 à l'Observatoire Royal de Belgique, il fut au Service séismologique le Collaborateur de M. O. Somville, qu'il remplaça comme chef du service séismologique en 1945.

Il se consacra alors à moderniser la station séismologique d'Uccle, qui est aujourd'hui l'une des mieux équipées du monde. En même temps il entreprit de vastes travaux sur la séismicité de la Belgique et ses relations avec les anomalies magnétiques et gravimétriques.

En août 1948, à Oslo, lors de la VIIIe Assemblée Générale de l'Union Géodésique et Géophysique Internationale. il avait été élu Vice-Président de l'Association Internationale de Séismologie et c'est lui qui assura l'organisation de l'Assemblée tenue à Bruxelles, en août 1951, par l'U.G.G.I.

Le travail considérable qu'il fournit à cette occasion, et alors qu'il était déjà souffrant, a certainement hâté sa mort.

Captain Nicholas H. Heck, formerly President of the Seismological Association of the IUGG and Chief of the Division of Geomagnetism and Seismology (now Division of Geophysics) of the United States Coast and Geodetic Survey, died December 21, 1953 at the age of 71. He was born in Heckton Mills, Pennsylvania and graduated from Lehigh University in 1903. Later his Alma Mater awarded him a degree in civil engineering and an honorary degree of Sc. D. Fordham University also awarded him a Sc. D. degree. Captain Heck entered the commissioned service of the United States Coast and Geodetic Survey in 1904, serving that Bureau until his retirement in 1945. He became Chief of Division of Terrestrial Magnetism December 1921. In 1925, Seismology was added to his responsibilities and he was largely instrumental in developing the teleseismic and strong-motion program of that Bureau. Earlier he played a large part in developing the wire drag method. He was the

(1) Le Secrétaire Général tient à remercier très vivement Monsieur J. Cl. de Bremaecker non seulement pour le travail si fructueux qu'il a fourni au cours des séances elles-mêmes, mais encore pour le soin avec lequel il a bien voulu revoir et compléter les notes qui ont servi à établir les présents Comptes Rendus.

author of a large number of scientific articles including a popular book, « Earthquakes ». He was author of various publications concerning wire drag method of off shore sounding; radio acoustic positioning; velocity of sound in sea water; and earthquake history of the United States. He was named the fourth recipient of the William Bowie Medal in 1942. He had been elected President of the Seismological Association at the Assembly of Edinburgh on September 22, 1936.

Frank Wenner, Consulting physicist and geophysicist and formerly Chief of the Resistance Measurement Section, Bureau of Standards for 30 years, died in Washington, D. C. February 7, 1954 at the age of 81. He graduated from Knox College in 1899 and received his doctorate from the University of Pennsylvania in 1909. He was awarded an honorary doctor of science degree from that University in 1942. He was well known for his development of the Wenner horizontal seismograph and the Wenner accelerometer used in the engineering-seismology program of the United States Coast and Geodetic Survey. The technical report « A New Seismometer Equipped for Electromagnetic Damping and Electromagnetic and Optical Magnification », was one of the first comprehensive treatises on the theory of the electromagnetic seismograph and an excellent reference for the determination of response curves.

He received the John Price Witherill Medal of the Franklin Institute for his development work in seismology.

Since his retirement in 1943, he has been a consulting physicist with the Carnegie Institution of Washington, the Applied Physics Laboratory of John Hopkins University, and the Research and Development Board of the National Military Establishments.

On trouvera dans le Rapport National Japonais quelques notes biographiques concernant le Professeur *Y. Otsuka,* décédé le 7 août 1950, le Professeur *H. Nagaoka,* décédé le 11 décembre 1950, le Professeur *A. Tanakadate,* décédé le 21 mai 1952, et le Dr *S. Homma,* décédé le 23 octobre 1953.

Les Drs *Risburo Tayama* et *Kiyosuke Kawada* ont trouvé la mort dans la catastrophe qui a causé la perte du navire hydrographique « Fifth Kaiyo-maru » le 24 septembre 1952.

2. Rapport du Secrétaire Général

Le Secrétaire Général, Prof. *Rothé,* présente son rapport :

Mes chers collègues,

Je dois vous présenter un rapport sur l'activité de notre association et de son Secrétariat pendant les trois années qui viennent de s'écouler. Je m'efforcerai de le faire aussi brièvement que possible.

A la suite de l'Assemblée de Bruxelles en 1951, notre programme de travail s'est trouvé élargi, puisque notre association a reçu la charge de coordonner non seulement les recherches de séismologie pure, mais encore celles qui concernent la Physique de l'Intérieur de la Terre.

Vous aviez à Bruxelles désigné des rapporteurs :

M. le Professeur Dr Vening-Meinesz (Tectonophysique) ;

M. le Directeur Jean Goguel (Interprétations gravimétriques) ;

M. le Dr Bullard (Géothermie et Radioactivité) ;

M. le Professeur J.-T. Wilson (Géothermie et Radioactivité) ;

M. le Professeur Harold Jeffreys (Elasticité et Plasticité) ;

M. le Dr Robert Stoneley (Elasticité et Plasticité).

Ces rapporteurs ont proposé des sujets de discussion et établi des listes de personnalités et de chercheurs intéressés aux divers chapitres de la Physique de l'Intérieur de la Terre. Votre Secrétaire s'est tenu en contact avec ses collègues des trois autres Associations plus directement intéressées à ce travail commun : Géodésie, Magnétisme terrestre, Volcanologie, et c'est ainsi qu'a été préparé le programme des séances groupées que vous trouvez rassemblées dans notre agenda du lundi 20 au mercredi 22 septembre. Nous souhaitons que cet effort de coordination aboutisse à un réel progrès dans l'étude en commun de phénomènes qui intéressent en fait les membres de plusieurs Associations.

Et ceci m'amène à vous dire quelques mots encore sur l'organisation de notre Assemblée de Rome. Sa durée totale restant limitée, il devenait nécessaire devant le nombre considérable de communications qui ont été annoncées, de prévoir des séances spéciales aux mêmes heures que celles consacrées à la Physique de l'Intérieur de la Terre. Notre Bureau a choisi pour ces séances spéciales des sujets particuliers évitant à nos collègues un choix trop difficile : agitation microséismique, appareillage séismique.

Je souhaite que l'horaire qui vous a été distribué puisse donner satisfaction aux uns et aux autres.

Je résume rapidement l'activité de notre Secrétariat depuis 1951, activité que vous connaissez par les publications que vous recevez tous, je pense, régulièrement.

1° *Rédaction et impression des Comptes rendus de l'Assemblée de Bruxelles et impression des mémoires présentés à Bruxelles devant notre Association.*

Seuls ont été publiés les mémoires qui n'avaient pas été imprimés dans d'autres revues scientifiques. Ces mémoires ont constitué le 18e fascicule des publications scientifiques de notre Association. Vous trouverez dans le compte rendu financier, qui vous a été remis, les charges qui en résultent pour notre Association : 400.000 francs pour les comptes rendus; 520.434 francs pour le fascicule 18. Ces frais ont été partiellement couverts par une subvention totale de 262.485 francs en provenance de l'UNESCO; la différence restant par conséquent à la charge de notre Association. Il sera important d'avoir ces chiffres présents à l'esprit lorsque notre Conseil discutera les projets du Secrétariat général de l'Union.

2° *Rédaction et impression du Bulletin Mensuel du Bureau International.*

Au fur et à mesure que le nombre des stations équipées d'appareils sensibles — de séismographes verticaux à courte période, en

particulier — s'accroît, le volume de données à trier et à classer pour la préparation de notre bulletin mensuel s'accroît aussi.

L'assistant technique, M. Marzi, qui appartient à notre Bureau depuis 1950, engage chaque mois une lutte contre la montre pour achever son travail dans les délais voulus : 1446 séismes ont été étudiés en 1951, 1672 en 1952, 1693 en 1953.

Des épicentres aussi nombreux que possible sont indiqués dans ce bulletin. Dans ce travail de déterminations, nous sommes aidés par l'excellent travail préliminaire effectué par l'U.S. Coast and Geodetic Survey à Washington avec la collaboration d'un grand nombre de stations séismologiques mondiales. Bien souvent, par conséquent, nous n'avons qu'à reprendre les déterminations effectuées à Washington en les vérifiant sur l'ensemble des données reçues.

Par ailleurs, la réunion de Stuttgart de la Commission Séismologique Européenne nous a chargés d'effectuer des déterminations rapides pour les séismes parfois assez faibles et assez peu nets, qui se produisent en Europe et dans le Bassin méditerranéen. Bien entendu, ces déterminations résultent des données que nous font parvenir rapidement nos collègues européens ou d'Afrique du Nord, que je remercie ici pour leur collaboration. Le travail séismologique est vraiment un travail de collaboration constante entre les différents observatoires. Il y a peu d'exemples, je crois, de sciences qui aient plus besoin d'un tel travail commun permanent.

Permettez-moi de rappeler ici la détermination qui fut faite à Strasbourg, le 31 mars dernier et relative à ce si curieux séisme d'Espagne. Dès que nous fûmes en possession des données de Tortosa, Alger, Averroes et Lisbonne, où les premières ondes arrivaient à peu près au même instant, il nous fut possible de déterminer un épicentre précis, et la comparaison des temps d'arrivées aux autres stations européennes nous conduisait à l'étonnante surprise d'un foyer à 600 km. de profondeur. Si je rappelle cet exemple, c'est aussi pour dire que ce travail de détermination d'épicentres, que nous poursuivons d'année en année, pourrait paraître fastidieux et monotone, la géographie séismologique passant pour être aujourd'hui bien connue. La détermination du 29 mars 1954 est une preuve que des surprises peuvent nous être encore réservées dans ce domaine.

Grâce à l'achat, par l'Université de Strasbourg, d'une machine à imprimer Vari-Typer, nous avons pu, depuis le 1er juillet 1953, améliorer la présentation du bulletin tout en réalisant une économie appréciable sur le papier et sur les frais postaux. Ici aussi nous recevons une aide efficace de l'UNESCO, aide qui était de 140.000 francs en 1951, de 175.000 en 1952 et qui s'est élevé à 455.000 en 1953. Pour 1954, la subvention totale atteindra 805.000, mais il faut s'attendre à voir cette subvention diminuer sensiblement dans les années qui viennent.

Je vous ai cité à plusieurs reprises dans ce rapport l'aide que nous apporte l'UNESCO. C'est une des tâches de votre Secrétaire de prévoir les demandes qu'il y a lieu de présenter à cet organisme par l'intermédiaire du Secrétaire Général de l'Union et du Conseil des Unions scientifiques. Cette tâche est souvent délicate, car les demandes doivent actuellement être présentées plus de deux ans à l'avance.

Je tiens à remercier, à cette occasion, le Secrétaire Général de l'Union, M. Laclavère, qui m'a toujours témoigné une grande compréhension.

3° *L'International Seismological Summary.*

Dans notre gratitude envers l'UNESCO, nous ne devons pas oublier non plus l'importante subvention que cet organisme verse à l'International Seismological Summary, subvention qui a dépassé 2 millions de francs français en 1951 et qui en 1953 était encore de 1.428 livres, soit environ 1.400.000 francs. C'est grâce à cette subvention jointe à celle que verse le Trésor britannique que le service de l'International Seismological Summary peut fonctionner de façon efficace, ainsi que vous le rapportera tout à l'heure son Directeur, le Professeur Jeffreys.

4° *La Réunion de la Commission séismologique européenne.*

Enfin, je ne veux pas oublier non plus que l'UNESCO a facilité la réunion que, sous la présidence du Professeur Hiller, la Commission Séismologique Européenne a tenue à Stuttgart du 23 au 28 septembre 1952. Les comptes rendus de cette réunion ont été rapidement publiés, grâce à une intervention de M. Laclavère, dans le nouveau Bulletin d'information de l'U.G.G.I. (Bulletin 2e année, N° 2, avril 1953, p. 184-294).

5° *L'étude de l'agitation microséismique.*

Sur l'invitation de l'Académie pontificale des Sciences, une réunion consacrée à l'étude des microséismes s'est tenue à Rome en novembre 1951. Cette réunion avait proposé l'organisation de semaines internationales d'études sur les microséismes et avait demandé au Secrétariat de notre Association d'inviter les stations séismologiques mondiales à faire des dépouillements détaillés d'heure en heure suivant des règles uniformes au cours de 2 périodes : du 16 mars au 5 avril 1952 et du 24 au 30 septembre 1952.

Pour la première période, 14 stations réparties sur le monde entier ont fait parvenir à Strasbourg les dépouillements horaires complets, 22 autres stations des dépouillements correspondant à 4 observatoires par jour.

Pour la deuxième période, en septembre, 6 stations seulement ont effectué des dépouillements.

Ces documents ont été partiellement utilisés par un jeune chercheur suisse, M. Saxer; ils sont conservés dans les archives du Bureau Central de Strasbourg. Je pense que, dans notre réunion qui sera consacrée aux microséismes le mercredi 22 septembre (matin), il y aura lieu de voir comment ces documents peuvent être utilisés et si cette étude en commun par semaines internationales doit être poursuivie.

Je terminerai ce rapport administratif et financier sur une note optimiste en indiquant que les réserves de l'Association, qui s'élevaient au 1er janvier 1951 à 2.513.523 francs, étaient au 1er janvier 1954 de 3.396.824 francs, dont 2.376 dollars (813.400 francs) étaient déposés à Pasadena et 2.376 livres (2.328.480 francs) à Cambridge (1). Je tiens les comptes détaillés à la disposition de la Commission des Finances que vous voudrez bien constituer.

(1) Cours des changes 1 £ = 980 francs; 1 dollar = 350 francs.

ANNEXE AU RAPPORT DU SECRETAIRE GENERAL

COMPTES DE L'ASSOCIATION DE SEISMOLOGIE ET DE PHYSIQUE DE L'INTERIEUR DE LA TERRE

1er janvier 1951 — 31 décembre 1953

I. — COMPTES STRASBOURG-CAMBRIDGE

RECETTES

	L.	s.	d.	frs français
En banque le 1-1-51 :	2374	0	3	154.647
En caisse le 1-1-51 :	—	—	—	32.356
Allocations de l'Union :				
1951 :	—	—	—	881.984
1952 :	900	—	—	—
1953 :	—	—	—	881.985
Virements de Cambridge à Strasbourg :				
1951 :	—	—	—	97.877
1952 :	—	—	—	97.793
1952 :	—	—	—	295.871
1953 :	—	—	—	293.942
Ventes de publications :				
1951—1953 :	—	—	—	37.985
Intérêts de banque :				
1951—1953 :	—	—	—	6.767
Remboursement de tirés à part et de frais :				
Tirés à part	—	—	—	37.716
Frais (UGGI, Strasbourg)	—	—	—	9.000
Subventions de l'UNESCO :				
I.S.S. 1951 :	2142	17	2	—
I.S.S. 1952 : 1857- 2-10 (1)	—	—	—	—
I.S.S. 1953 : 1428-11- 5 (1)	—	—	—	—
Assemblée de Bruxelles (Voyages)	—	—	—	122.500
Symposium Stuttgart	—	—	—	525.000
Symposium 1953 (2)	250	0	0	—
Bulletin mensuel 1951 :	—	—	—	140.000
Bulletin mensuel 1952 :	—	—	—	175.000
Bulletin mensuel 1953 :	—	—	—	455.000
Publications 1952 :	—	—	—	140.000
Publications 1953 :	—	—	—	122.485
Total :	5666	17	5	4.507.908

DÉPENSES

	L.	s.	d.	frs français
Dépenses de fonctionnement :				
Emoluments Mlle Schrapf 1951 :	—	—	—	126.845
id. 1952 :	—	—	—	154.435
id. 1953 :	—	—	—	152.700
Frais postaux 1951 :	—	—	—	98.744
Frais postaux 1952 :	—	—	—	121.087

(1) Chèques envoyés directement par le Secrétaire Général de l'UGGI à Sir Harold Jeffreys.

(2) reporté à 1954.

Frais postaux 1953 :	—	—	—	150.144
Papeterie	—	—	—	37.243
Assurances incendie et divers	—	—	—	4.093
Impôts	—	—	—	56.300
Virements de Cambridge à Strasbourg :				
1951 :	100	2	6	—
1952 :	100	12	6	—
1952 :	300	7	6	—
1953 :	300	7	6	—
Publications :				
Tirés à part C.O.P.E.I.	—	—	—	32.016
C.R. Assemblée de Bruxelles	—	—	—	400.000
Fascicule 18 (Bruxelles)	—	—	—	520.434
Préparation et impression du Bulletin mensuel :				
1951 :	—	—	—	540.851
1952 :	—	—	—	529.228
1953 :	—	—	—	755.609
Assemblée de Bruxelles :				
Voyages	34	8	0	36.282
Circulaires	—	—	—	16.472
Remboursement à l'UNESCO	—	—	—	56.737
Symposium de Stuttgart :				
Voyages	62	0	0	268.406
Impression des comptes rendus	—	—	—	195.338
Versements à l'I.S.S. :				
1951 :	2142	17	2	—
Balance :				
En banque le 31-12-53 :	2626	2	3	231.082
En caisse le 31-12-53 :	—	—	—	23.862
	5666	17	5	4.507.908

II. — COMPTE U.S.A. (Pasadena)

RECETTES

	dollars
En banque le 1-1-51 :	—
Allocations de l'Union :	
1951-1952 :	1507,95
1953 :	762,75
1954 (1) :	756,00
Intérêts de banque :	
1952 :	15,07
1953 :	15,23
1953 :	23,01
Total :	3080,01

DÉPENSES

Néant

(1) Versée le 28-12-53.

ADDITIF

Pour l'année 1954, la subvention accordée par l'U.N.E.S.C.O. à l'I.S.S. s'élève à 5.700 dollars (soit 2035-14-4 £). La subvention de l'U.N.E.S.C.O. pour le bulletin mensuel du Bureau International de Séismologie a été portée à 2.300 dollars (soit 805.000 francs). Enfin l'allocation de l'U.G.G.I. à l'Association reste maintenue à 1.170 £ (soit 882.000 francs déposés à Strasbourg et 756 dollars en compte à Pasadena).

Au 30 juin 1954, l'avoir de l'Association se décompose ainsi :

Strasbourg : 1.686.428 francs
Cambridge : 2425 - 17 - 3 Livres
Pasadena : 3110,81 Dollars

Nota : L'avoir à Strasbourg doit être diminué d'environ 300.000 fr. correspondant à des dépenses engagées au 30 juin 1954.

Strasbourg, le 1er juillet 1954.

Le Secrétaire Général : *Professeur J.-P. Rothé.*

3. Constitution d'une Commission des Finances

Le *Président Gutenberg* remercie le Secrétaire Général de son rapport. Pour constituer la Commission des Finances, il est nécessaire de désigner trois membres de l'Assemblée.

Sont nommés membres de la Commission des Finances : MM. *Bath, Hiller* et *Hodgson.*

4. Rapport du Président de la Commission de l'I.S.S.

Professor Gutenberg presents *Sir Harold Jeffreys* and points out the importance of the I.S.S. especially for smaller shocks for which the reports are often late, for instance, from Indian stations.

Le *Professeur Jeffreys* présente son rapport :

The « International Seismological Summary » continues to be housed at Kew Observatory. Considerable progress has been made since the Brussels meeting. In July 1951 the last part issued was for 1939 October-December. In March 1954 the last is for 1944 October-December, so that five year's data have been published in 2¾ years.

The parts issued for the war years up to 1942 were not much smaller that in previous years, but the later ones are substantially smaller. It remains to be seen whether the rate of preparation can be maintained when the post-war recovery takes place.

There have been several changes of staff. Miss Hunter, now Mrs. Sykes, who had done the greater part of the computation since 1946, has left. Mr. B. Elliott stayed for two years before leaving for military service. A Cambridge graduate in mathematics, Mr. J. H. Mc Donnell, was engaged last year but stayed for only six months. Several others have stayed only a short time. The present staff consists of Mr. Hughes, Mrs. I. Sanders, Miss V. Howe and Miss J. D. Batten. The normal number is five. It is particularly desirable that there should be an additional graduate, but we cannot offer prospects of promotion that would compete with the Civil Service and Industry.

The possibility of production by photo-lithography has been investigated, expert assistance being provided by the Royal Society. It appeared that some saving might be possible, but that the amount would be small. This is largely due to the very favourable terms offered by our printers. The largest item in the time taken for preparation is in the copying of observations from the bulletins on to cards, so that all data for each earthquake can be kept together, and there seems to be no way of avoiding or shortening this part of the procedure.

The chief items of income and the total expenditure have been as follows (in £) :

	Unesco	H. M. Treasury	U.G.G.I.	Expenditure
1951 (10 months)	2143	2000	—	1961
1951-2	1857	2000	—	3610
1952-3	1428	—	—	3441
1953-4 (to Mar. 31)	—	1000	200	2000 (approx.)

The UNESCO grant of £ 2035 was received after March. 31. The cash in hand on Aug. 31 was £ 2759.

The Treasury grant is conditional on the publication of seven quarterly parts per year and the receipt of a grant from the U.G.G.I. The fluctuations of income continue to give ground for anxiety.

I should like to record my thanks again to the Director of the Meteorological Office for accommodation at Kew Observatory and to Dr. G. D. Robinson for help with the administration. The printers, the Isle of Wight County Press, have helped greatly by increasing the rate of printing to keep pace with preparation.

I am due to retire from my post at Cambridge in 1956. This will be before the next general meeting of the U.G.G.I., and I wish to cease to be Director of the I.S.S. then or sooner. The I.S.A. should therefore consider at Rome what arrangements it wishes to make for the future of the I.S.S.

19 May, 1954.

ANNEXES AU RAPPORT DE SIR HAROLD JEFFREYS

1. — *REPORT OF THE DIRECTOR OF THE I.S.S. FOR 1951*

I have great pleasure in expressing my gratitude to Unesco for an increased grant of £ 2142.17.2 in the present year and to His Majesty's Treasury, through the Royal Society, for one of £ 2000 ; to Dr R. Stoneley, who acted as Director during my absence for six months in the United States ; and to the Director of the Meteorological Office for additional accommodation at Kew Observatory. Resolutions expressing the thanks of the International Seismological Association were passed at the meeting at Brussels in September, and the history of the I.S.S. was the subject of Dr Stoneley's presidential address. This address is being printed and will be circulated in a few days.

The grant from the British Treasury is conditional on an increased effort to make up arrears. Consequently two additional junior staff, Mr. B. Elliott and Miss G. Turner, were engaged during the summer. It is desirable that we should also be in a position to appoint an additional graduate assistant if a person with suitable

qualifications in seismology and statistics can be found. Our object is to produce solutions for two years' earthquakes per year until the lag has been reduced to three years.

The last part issued in 1950 was for the second quarter of 1939. At the moment of writing (1952 Jan. 4) the last issued is for the third quarter of 1940, so that we are in fact already recovering arrears, but very slowly.

An interesting feature of the accounts is that the income from sales of publications is nearly three times that of the previous year. This is a welcome indication of increased interest from outside bodies. A new list of Geocentric Direction Cosines has become necessary; the previous list already needed revision on account of the large number of new stations.

In view of the change in the financial year I should add that payments in November and December have included about £ 282 in salaries and £ 280 for printing. The actual balance at the end of 1951 will be about £ 3100.

HAROLD JEFFREYS.

Audited Accounts for 1951

Receipts

	£ s. d	£ s. d
Grants :		
United Nations Educational Scientific and Cultural Organisation	2,142. 17. 2	
H. M. Treasury (per Royal Society)	2,000 ——	4,142. 17. 2
Sale of Literature		51. 18. 1
Deposit Account Interest (6 months to 30th June 1951)		2. 7. 6
Total Receipts		4,197. 2. 9
Cash at Bankers and Cash in Hand 31st December 1950		1,468. 7. 9
		£ 5,665. 10. 6

Payments

	£ s. d
Salaries and Allowances (less Staff Superannuation Contributions)	1,203. 17. 2
Superannuation Contributions	158. 1. 3
National Insurance	29. 13. 3
Printing	526. 1. 4
Stationery and Postage	15. 17. 6
Cheque Books	14. 0
Maintenance of Calculating Machine	9. 9. 2
Accountancy Charges	3. 3. 0
Miscellaneous Expenses (including Travelling expenses)	14. 18. 5
Total Payments	1,961. 15. 1

Cash at Bank 31st October 1951 :

	£ s. d	
Deposit Account	3,677. 11. 10	
Current Account	22. 11. 6	
Petty Cash in hand 31st Ostober 1951 :		
London	2. 0 6	
Cambridge	1. 11. 7	3,703. 15. 5
		£ 5,665. 10. 6

We have prepared the foregoing Abstract Financial Statement from the books and vouchers and certify the same to be correct in accordance therewith.

7th January, 1952.

Peters, Elworthy and Moore
Chartered Accountants.

II. — *REPORT OF THE DIRECTOR OF THE I.S.S. FOR 1952*

1st February, 1952.

You will have received the I.S.S. financial statement and my report for 1951 January-October. I should like to mention some other matters not discussed in the report and should be grateful for any comments.

The grant from H. M. Treasury is made on condition that we make a strong effort to make up arrears, and we interpret this to mean that we must try to publish data for two years each year. Arrears can hardly be reduced below three years on account of the time it takes some stations to forward their data, but this minimum could be reached in about eight years if we carry out our programme. Special points that must be faced are (1) staff (2) rate of printing (3) finance.

At present we are publishing about 5 quarterly parts per year. In accordance with our plans we have already engaged two junior staff. The whole of the determination of epicentres is done by Mr. Hughes and takes up most of his time ; and if he was absent for any reason it would stop completely. We therefore need also a graduate assistant with qualifications in seismology and statistics.

The printing is done by the Isle of Wight County Press, which has been associated with the work since John Milne's reports. It is uncertain whether they can increase their speed. This difficulty concerns every printing establishment in this country, partly on account of slow recruitment of compositors and partly through shortage of paper. I have therefore little hope that any improvement would result from a change to other printers, and any change would increase the expense. What I should contemplate, if the printers cannot increase the speed sufficiently, is that an occasional volume should be produced by another firm as a special job (care being taken to keep the size of page the same). This might be done either by printing or by photo-litography. The latter method appears to cost slightly more if the firm has to prepare the special typescript needed.

The Royal Greenwich Observatory finds it more satisfactory to prepare this itself and avoid proof-correction.

At the moment the financial situation is satisfactory. Unesco and the Treasury have promised $ 5200 and £ 2000 respectively for 1952. We must, however, remember that other claims on Unesco are continually increasing and that the Treasury is certain to be seeking ways of economizing. It would be much more convenient if a regular endowment was available — if somebody could give us £ 25.000 spread over the next five years planning would be much easier. This course was discussed informally at Brussels, and Dr Fraser and M. Laclavère have made considerable efforts to obtain such an endowment, but so far without success.

It has been suggested that a small charge should be made to the observatories for receiving the I.S.S. $ 5 per volume to contributing stations and $ 10 to outside purchasers have been suggested. At present the printing cost is about $ 1,40 per copy; distribution is free to contributing stations and at a little over cost price to others. About 400 stations receive the I.S.S. and if all agreed to make the payment the resulting income, at five issues per year, would be $ 2.800 per year. If many did not pay, the income would be correspondingly reduced, without any proportionate reduction in cost of printing. This source would therefore provide only a small part of the total cost, and the trouble of collecting and cashing cheques would be considerable. I should, however, be glad to receive any comments.

HAROLD JEFFREYS.

Audited Accounts for 1952

Receipts :	£ s. d.	£ s. d.
Grants :		
United Nations Educational Scientific and Cultural Organisation	1,857 2 10	
H.M. Treasury (per Royal Society)	2,000 0 0	3,857 2 10
Sale of Literature		57 5 10
Deposit Account Interest		36 10 8
Total receipts :		3,950 19 4
Cash at Bankers and Cash in Hand 31st October 1951 ..		3,703 15 5
		£ 7,654 14 9
Payments :		
Salaries and Allowances (less Staff Superannuation Contributions)		1,584 1 1
Superannuation Contributions		231 18 0
National Insurance		67 1 1
Printing		1,541 16 2
Stationery and Postage (including typing)		46 18 1
Bank Charges and Cheque Books		2 1 6
Purchase of second-hand Brunsviga Calculating Machine		105 0 0

Maintenance of Calculating Machine			9 11 0
Accountancy Charges			5 5 0
Miscellaneous Expenses (including Travelling Expenses)			16 16 4
Total payments :			3,610 8 3
Cash at Bankers 31st October, 1952 :			
Deposit Account	3,971 5 4		
Current Account	74 0 7		
Petty Cash in hand 31st October, 1952 :			
London	13 11		
	4,045 19 10		
Less : Petty cash overdrawn Cambridge	1 13 4		4,044 6 6
		£	7,654 14 9

We have prepared the foregoing Abstract Financial Statement from the books and vouchers and certify the same to be correct in accordance therewith.

14th January, 1953.

Peters, Elworthy and Moore
Chartered Accountants.

III. — *REPORT OF THE DIRECTOR OF THE I.S.S. FOR 1953*

During the financial year 1952 Nov. 1 to 1953 Oct. 31, seven quarterly parts were issued and distributed, namely those for 1942 January-March to 1943 July-September. An equal number were issued in the previous year, so that arrears are now being made up at a considerable rate.

The parts up to 1943 Oct-Dec. have been nearly as large as pre-war ones. It had been expected that fewer stations would be active during the war, but the reduction has in fact been barely appreciable hitherto. The parts for 1944 January-June are, however, only about half as large as previous ones; it remains to be seen how long the recovery will take. Some stations have not yet sent in their readings for 1944.

No grant was received from the Royal Society in the financial year, but £ 1.000 was received after the close of the year.

The normal staff consists of five members, but there are frequent changes, and in consequence the average number fully active at any time is less. Mr. Brian Elliott, who had done excellent work for two years, left during the year for military service. Dr R.I.B. Cooper assisted voluntarily for three months.

I have wished for a long time to employ an additional graduate, who would be capable of superintending the work if Mr. Hughes was absent for any reason. Mr. J.H. Mc Donnell was appointed in July for this purpose, but has left (Jan. 1954) for another post. The staff is in consequence reduced to four (Mr. Hughes, Mrs. Sanders,

Miss V. Howe, and Miss J.D. Batten). Unfortunately it is not usually possible to engage new staff except between June and October, and we may be understaffed for six months.

The difficulties about employing an additional graduate are of course that there is no reasonable prospect of promotion and that much higher salaries are obtainable in industry. It may be worth while to consider whether the difficulty would be reduced if the I.S.S. was part of a larger organisation.

It has been suggested that, instead of printing, some method of direct reproduction of typescript might be adopted. This possibility was examined during the year, in consultation with the Royal Society, but it did not appear likely to afford much advantage.

I must take this opportunity of recording my thanks to the printers, the Isle of Wight County Press, for their co-operation in increasing the rate of printing to keep pace with preparation.

Unesco has promised a grant of £2.100 for 1953-54. By the kindness of the Director of the Meteorological Office the work continues to be done at Kew Observatory, and the Superintendent, Dr G.D. Robinson, has given much valuable help with the administration.

HAROLD JEFFREYS.

Audited Accounts for 1953

Receipts :	£ s. d.	£ s. d.
Grants :		
United Nations Educational, Scientific and Cultural Organisation .	1,428 11 5	
H. M. Treasury (per Royal Society)	— — —	1.428 11 5
Sale of Literature		32 — 11
Deposit Account Interest to 30th June 1953		76 1 10
Total Receipts :		1,536 14 2
Cash at Bankers and Cash in hand 31st October 1952		4,044 6 6
		£ 5,581 — 8
Payments :		
Salaries and Allowances (less Staff Superannuation Contributions)		1,693 5 10
Superannuation Contributions		201 14 9
National Insurance		92 16 8
Printing		1,342 11 3
Stationery and Postage (including Typing)		72 14 10
Bank Charges and Cheque Books		4 17 —
Maintenance of Calculating Machines		16 8 7
Accountancy Charges		3 13 6
Miscellaneous Expenses (including Travelling Expenses)		13 7 4
Total Payments :		3,441 9 9

Cash at Bankers 31st October 1953 :				
Deposit Account	2,025	18	7	
Current Account	110	6	6	
Petty Cash in Hand 31st Oct. 1953 :				
London	1	3	$2\frac{1}{2}$	
Cambridge	2	2	$7\frac{1}{2}$	2,139 10 11
				£ 5,581 — 3

We have prepared the foregoing Abstract Financial Statement from the books and vouchers, and certify the same to be correct in accordance therewith.

10th December 1953.

Peters, Elworthy and Moore,
Chartered Accountants.

5. Discussion du Rapport du Professeur Jeffreys

A une question du *Professeur Rothé,* Monsieur *J.S. Hughes* indique que la collection des données russes est complète jusqu'en 1952. Le travail de l'I.S.S. peut donc être poursuivi sans difficultés.

Dr de Bremaecker asks about using I.B.M. and/or electronic computers. *Professor Jeffreys* answers that they do not appear to be practical for this purpose.

Prof. Gutenberg says that in Pasadena the texts are typed in final form at the Seismological Laboratory and are then sent to the University Press where they are reproduced by offset; the cost is 50 % less than printing. There have been many shocks given in the I.S.S. that were mislocated, one due to the absence of New Zealand data. The focal depths are somewhat uncertain, it is possible that the I.S.S. depths are too large. Thanks are voted to the I.S.S. workers.

Prof. Gutenberg suggests to give the focal depth in km instead of in fraction of the Earth's radius or even in fraction of this quantity minus 33 km as at present.

Prof. H. Jeffreys suggests doing both : the present system would be maintained and the number of km given. Prof. Gutenberg agrees, but suggests having the new tables give for focal depths in km.

M. Peterschmitt demande à partir de quelle origine seront comptées les profondeurs exprimées soit en km, soit en fractions du rayon terrestre.

Prof. Gutenberg gives some precision : The depths in km are counted from the surface whereas the depths in fraction of the Earth's radius are counted from the Mohorovicic discontinuity (33 km deep).

A motion to the effect of having depths given in km in addition to the present method is unanimously adopted.

Prof. H. Jeffreys points out the cheapness of the present system of reproduction : the printer charges very little for the I.S.S.. *Prof. Gutenberg* says that in Pasadena printing is expensive and the Secretary is available anyway.

Prof. Gutenberg suggests a motion to the General Secretary of the Union concerning the I.S.S., asking that adequate funds be voted for continuing its printing.

Dr. Stoneley says that this is both a scientific and a financial vote. The text will be given later. *Dr. Stoneley* and *Prof. Jeffreys* will make the text. The motion will ask that the funds be increased.

La séance est levée à 10 h. 45 m.

DEUXIÈME SÉANCE

MERCREDI, 15 SEPTEMBRE (après-midi)

Programme

6. — Graphiques de durées de propagation.
7. — Dictionnaire séismologique.
8. — Catalogue des stations séismologiques mondiales.
9. — Direction de l'I.S.S.
10. — Divers.

La séance est ouverte à 15 h. 05.

6. Graphiques de durées de propagation

Madame Labrouste expose le principe de la construction des diagrammes de propagation destinés à faciliter l'interprétation des séismogrammes.

Le Service séismologique de l'Institut de Physique du Globe de Paris a exécuté, avec la collaboration des Services spécialisés de l'Institut Géographique National, des graphiques permettant un contrôle rapide de l'interprétation des séismogrammes.

A cet effet, les courbes ont été tracées sur un support en plastique transparent (astralon) en adoptant, comme échelle des temps, celle des séismogrammes, ce qui permet de superposer directement le graphique au séismogramme étudié.

Les temps, portés en abscisses, représentent les différences entre les durées de propagation des différentes phases (X) et celles des ondes P ou PKP, selon la distance. En ordonnées, sont portées les distances angulaires, en degrés, avec une échelle de correspondance en km. La présence d'une échelle à chaque extrémité du graphique permet une lecture précise des ordonnées. Les pointés ont été faits avec une grande précision au moyen d'un coordinatographe.

Les graphiques actuellement disponibles se rapportent respectivement aux foyers superficiels et aux profondeurs $h = 0{,}01$ (97 km) et $h = 0{,}09$ (606 km). D'autres sont en préparation.

Le premier graphique traduit simplement celles des Tables *Jeffreys-Bullen* (1948) qui concernent les foyers superficiels. Pour les foyers profonds, les Tables ci-dessus ont été complétées par celles de nombreuses phases réfléchies, notamment celles des ondes réflé-

chies près de l'épicentre. Le calcul des durées de propagation correspondantes a été fait à partir des Tables de corrections publiées par H. *Jeffreys* et K. E. *Bullen*, en suivant les règles données par le Professeur *Jeffreys*. Les courbes ainsi obtenues sont évidemment moins précises que les autres, mais elles fournissent néanmoins un guide suffisant pour l'interprétation des séismogrammes.

On a, en outre, adjoint à chaque graphique une courbe auxiliaire donnant les différences P-PKP entre 105° et 140°; la courbe des P a été calculée par extrapolation linéaire à partir de 105°.

Enfin, les graphiques ont été complétés par trois courbes relatives aux ondes superficielles de *Love* et de *Rayleigh*. Dans l'impossibilité de fixer avec précision les durées de propagation des ondes superficielles, on s'est borné à définir, par ces trois courbes, les limites entre lesquelles les ondes de *Love* et les ondes de *Rayleigh* peuvent apparaître.

Les graphiques originaux ont été construits à l'échelle de 2 cm/minute. Des copies sur film indéformable peuvent être fournies par le *Bureau Central Séismologique International* à l'une des trois échelles suivantes : 1,5 cm/min, 2 cm/min. et 3 cm/min.

Le prix de vente d'un jeu de six planches (une planche donnant les durées X-P et une autre les durées X-PKP pour chacune des trois profondeurs de foyer) est fixé à 13.000 francs pour les échelles de 1,5 et 2 cm/min. et à 17.000 francs pour l'échelle de 3 cm/min.

Des travaux sont en cours pour dresser des graphiques correspondant aux profondeurs : 33, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650 à 700 km.

M. Jensen demande quand ces derniers diagrammes pourront être livrés.

Mme Labrouste répond que la date de livraison dépendra du nombre de commandes.

Dr. Bath suggests that the seismograms be read first without any knowledge of where the phases should arrive. Otherwise large but not identified phases may be overlooked and small phases falling on the curves may be incorrectly included in the readings.

Prof. Gutenberg strongly suggests that one first read seismograms without travel time curves and that one then try to match the readings with the curves. One should also report strong unidentified phases.

Le Prof. Rothé fait ressortir que les diagrammes établis par Mme Labrouste doivent permettre d'avoir immédiatement une vue générale de l'interprétation des séismes et une idée sur la distance approximative. Il rappelle aussi que pendant longtemps la phase pP était simplement désignée par la notation « i ! » lorsqu'on ne savait pas encore à quelle phase correspondait cet impétus très net. Il convient donc d'indiquer de toute façon les impétus bien visibles.

Prof. Bullen remarks that once seismologists knew where to expect the phase PKJKP, they read any small phase which happened to be there, but that there were numerous phases that were just as conspicuous.

Le *Prof. Hiller* soulève la question des différentes tables et voudrait qu'on utilise uniquement les tables Jeffreys-Bullen.

Prof. Gutenberg does not think that the difference between

existing tables or curves is serious enough to cause misidentification of phases.

Dr. Carder remarks that different instruments record a phase at somewhat different times.

Mme Labrouste rappelle qu'une de ses élèves a fait une étude sur le séisme du 1er avril 1946 et a mis en évidence des écarts régionaux en groupant respectivement les stations japonaises, américaines et européennes. Ces écarts paraissent dûs à des différences dans les sensibilités des appareils utilisés.

Prof. Gutenberg : For the earthquake of July 1952 (Kern County shock) many European stations gave many S phases. This may be due to local differences. The first phase S may be S refracted to P somewhere near the station, or a P refracted to S somewhere near the source.

M. Peterschmitt souligne l'importance du mécanisme au foyer qui peut introduire des écarts suivant les azimuts.

7. Dictionnaire séismologique

Le *Professeur Guyot* présente le rapport de la Commission du dictionnaire :

Lors de la dernière Assemblée générale à Bruxelles, l'Association internationale de Séismologie a désigné une commission de 3 membres pour mettre au point un dictionnaire séismologique. Cette commission comprend : Madame Y. Labrouste de Paris, M. C. F. Richter de Pasadena (U.S.A.) et moi-même. Immédiatement après la séance de Bruxelles, je me suis mis en rapport avec M. Richter qui n'assistait pas à cette réunion. Il me promit son appui mais ne m'a plus donné signe de vie ensuite. Madame Labrouste, au contraire, a entrepris de revoir et de compléter les définitions que j'avais proposées. Nous avons eu une entrevue en septembre 1953, au cours de laquelle nous nous sommes mis d'accord sur un certain nombre de définitions. J'exprime mes vifs remerciements à Mme Labrouste qui continue son travail. Le dictionnaire n'est pas encore terminé, mais une grande partie du travail est faite et il conviendrait que l'Association se prononce sur les définitions choisies.

Après l'Assemblée de Bruxelles, je me suis mis en rapport avec l'UNESCO, département des Sciences exactes et naturelles, qui avait demandé à notre Association, en date du 9 septembre 1950, de donner suite aux vœux de la Conférence Internationale sur l'analyse de documents scientifiques tenue en 1949. La Conférence recommandait : « que de bons dictionnaires bilingues ou polyglottes, illustrés si possible, soient établis pour tous les domaines de la science et de la technique, et que ces dictionnaires tiennent compte des différentes acceptions de certains termes selon les pays ». M. J.E. Holmstrom me répondit en date du 3 octobre 1951 et me fournit toute la documentation concernant la manière de concevoir les dictionnaires en plusieurs langues. Il laissait entrevoir une collaboration financière de l'UNESCO de l'ordre de 500 dollars pour la publication de l'ouvrage. Lors de son passage à Neuchâtel le 10 octobre 1951, il voulut bien s'y arrêter pour que nous puissions prendre contact et discuter de notre projet. Depuis lors, l'UNESCO m'a fait parvenir toutes ses

publications concernant les dictionnaires. Pour les mettre en pratique, il faut tout d'abord attendre que toutes les définitions françaises soient au point.

La question se pose maintenant de savoir si l'Association désire que toutes les définitions soient choisies avant d'en prendre connaissance ou si elle veut contrôler le travail déjà fourni par la Commission depuis 1951. Dans ce dernier cas, il conviendrait de désigner qui examinera le projet ? L'Assemblée plénière ou une Commission élargie ? Pour que l'UNESCO patronne notre travail, il faut que chaque définition soit adoptée par l'Association.

Le *Professeur Gutenberg* signale que le Professeur Richter a été très absorbé par l'étude des nombreux séismes qui ont eu lieu au voisinage de Pasadena.

Monsieur Guyot est amené à préciser que l'UNESCO veut d'abord un dictionnaire en une seule langue; on peut espérer recevoir de l'UNESCO un subside assez important pour la publication.

Le *Président Gutenberg* suggère que la Commission du dictionnaire comprenne des membres de différentes langues.

Une résolution est adoptée invitant la Commission du dictionnaire à poursuivre son travail et à recruter par elle-même de nouveaux membres.

Le *Professeur Rothé* met l'Assemblée au courant du projet conçu par la Commission pour l'Etude de l'Ecorce terrestre au cours du Congrès international de Géologie tenu à Alger en 1952.

Cette commission, présidée par le Professeur Fourmarier de Liège. a décidé de préparer un dictionnaire ou lexique des termes géologiques en prenant comme point de départ le livre classique de Heim et De Margerie.

La Commission, ayant appris que l'Association Internationale de Séismologie préparait de son côté un dictionnaire, a demandé à Monsieur Rothé de servir d'intermédiaire entre les deux organismes.

A la suite de ce contact il a été décidé qu'un certain nombre de noms plus géologiques que séismologiques ne figureront pas dans le dictionnaire séismologique et seront signalés à la Commission pour l'Etude de l'Ecorce terrestre.

8. Catalogue des stations séismologiques mondiales

Le *Professeur Rothé* présente de la part du Professeur Bourgeois, Directeur de l'Observatoire Royal de Belgique, le volume intitulé «Liste des Stations séismologiques mondiales». Cet ouvrage a été préparé par Monsieur Charlier et achevé par Monsieur Van Gils et contient pour chaque station des renseignements concernant les coordonnées, l'appareillage utilisé, les constantes des instruments, son historique résumé, etc.

Monsieur Bourgeois aimerait pouvoir publier prochainement une liste complémentaire; il compte envoyer à nouveau, au début de 1955, des formulaires aux stations n'ayant pas répondu lors de l'enquête préliminaire et désire attirer l'attention des membres de l''Association sur ce sujet.

L'Assemblée décide d'envoyer une lettre de remerciements au

Directeur de l'Observatoire Royal d'Uccle et d'envoyer une copie de cette lettre à Madame Charlier.

Le *Président Gutenberg* estime qu'il est nécessaire de publier une liste additive, un grand nombre de stations ayant en effet modernisé leur appareillage; d'autre part, le nombre des stations russes a plus que doublé.

Le *Professeur Rothé* propose que les circulaires envoyées par l'Observatoire soient accompagnées d'une mention montrant que l'Association prend intérêt à ce que les réponses soient aussi nombreuses et exactes que possible.

Des exemplaires de la « Liste des Stations séismologiques mondiales » peuvent être fournis par le Service séismologique de l'Observatoire Royal de Belgique, 3, avenue Circulaire, Uccle (Belgique).

9. Direction de l'I.S.S.

Sir Harold Jeffreys informe l'Assemblée qu'il veut bien continuer à assumer pendant 3 ans encore la direction de l'équipe qui prépare l'I.S.S.

Les membres remercient Sir Harold Jeffreys par des applaudissements chaleureux.

10. Divers

Le *Professeur Bullen* propose un vœu à transmettre au Gouvernement Australien et l'invitant à installer une nouvelle station séismologique à Port Moresby.

Le *Président Gutenberg* appuie ce vœu et souligne l'importance très grande de cette station.

Le texte du vœu sera soumis ultérieurement à l'Assemblée pour être transmis au Secrétaire Général de l'Union.

M. E. Peterschmitt voudrait voir établir une liste de coordonnées géocentriques à 5 décimales. Si la table à 4 décimales actuellement utilisée est en général suffisante, cependant pour certains travaux les calculs à 5 décimales seraient plus efficaces.

Madame Labrouste propose que les coordonnées géocentriques soient portées sur le catalogue des stations séismologiques.

La séance est levée.

TROISIÈME SÉANCE

JEUDI, 16 SEPTEMBRE (matin)

Programme

11. — Distribution des Rapports Nationaux et vœux.
12. — Activité séismologique au Congo belge.
13. — Année Géophysique Internationale.

14. — Election du nouveau Bureau.
15. — Rapport de la Commission des finances.

La séance est ouverte à 9 heures.

11. Distribution des Rapports Nationaux et Vœux

Les Rapports Nationaux disponibles sont distribués aux membres de l'Association. Le texte de ces Rapports est publié en annexe des présents Comptes rendus.

Présentation de vœux :

Dr. Carder expresses the desire to have a resolution favoring the continuation of epicentral location cards.

The following resolution was unanimously adopted :

« Considering the great service to seismological research rendered by the epicenter cards issued so promptly by the United States Coast and Geodetic Survey, the U.G.G.I. resolves that the U.S. Coast and Geodetic Survey be urged to continue issuing these cards as at present and if possible that this service be improved, and be it further

Resolved that a copy of this resolution be sent to the Secretary of Commerce, U.S.A. ».

Sir Harold Jeffreys is anxious to see the missing Seismological Bulletins MSI of the U.S. Coast and Geodetic Survey published with a minimum of delay.

La résolution suivante est présentée :

« It would be desirable to have the missing bulletins published by the U.S. Coast and Geodetic Survey ».

This resolution passed by a large majority.

Le *Dr. Wanner* tient à remercier le U.S. Coast and Geodetic Survey du travail considérable qu'il fait pour déterminer rapidement les épicentres principaux.

12. Activité séismologique au Congo belge

M. *J. Cl. de Bremaecker* présente un aperçu sur l'activité séismologique au Congo belge. Le *Professeur Rothé* remercie *M. de Bremaecker* et se réjouit de l'installation des stations séismologiques au Congo belge. Les nouvelles données jointes à celles obtenues dans les stations plus anciennes de Tamanrasset, d'Afrique du Sud et de Tananarive permettent d'accroître nos connaissances séismologiques sur le continent africain.

Le *Président Gutenberg* demande où en sont les stations de l'Afrique occidentale. Le *Professeur Rothé* répond que la station de M'Bour est actuellement en fonctionnement normal et que son équipement sera prochainement amélioré.

13. Année Géophysique Internationale.

Dr. Stoneley : A suggestion was adopted by the British National Committee saying to put up seismographic stations at the occasion of expeditions to far away countries.

Le *Professeur Rothé* regrette qu'il ne soit pas dans l'esprit de

la Commission Internationale de faire exécuter des travaux séismologiques pendant l'Année Géophysique Internationale.

Dr. Stoneley believes that the Commission is considering a change of viewpoint.

Le *Dr Bonelli* signale qu'il compte installer une station séismologique dans une colonie espagnole sur l'Equateur pendant l'année géophysique.

La résolution suivante est proposée :

« That the Association favors installing temporary stations during the Geophysical Year in certain regions of the world like the Pacific and the Antarctic taking advantage of the expeditions which will be made during the year ».

The resolution was unanimously adopted.

Autres résolutions : Le *Professeur Wadati* et le *Professeur Hiller* interviennent pour proposer des résolutions concernant l'organisation d'explosions à but scientifique.

Ces résolutions seront étudiées ultérieurement.

14. Election du nouveau Bureau

President Gutenberg reminds the Assembly of the Rules :

Members from countries which were represented in the retiring Bureau are not eligible for offices in the new Bureau.

Dr. Stoneley suggests a list :

Président : Professor K. E. Bullen.

1er Vice-Président (langue anglaise) : Dr. K. Wadati.

2e » » (langue française) : Dr. E. Wanner.

Le Secrétaire Général, Prof. J.-P. Rothé, a été élu à l'Assemblée de Bruxelles pour 6 ans.

Dr. Heinrich suggests that the list be unanimously passed.

L'Assemblée adopte par acclamation la liste proposée.

Professor Bullen thanks the Members of the Association and feels very honoured.

15. Rapport de la Commission des finances

Le *Dr J. H. Hodgson* lit le rapport de la Commission des finances:

The Financial Committee consisting of MM. Hiller, Bath and Hodgson have met on the 15th of September to examine the accounts for the year 1951-1953. They have checked all the documents submitted and have found all to be in order. They propose that the accounts be accepted and desire to express their sincere thanks to Prof. Rothé for his careful work and also to M. Georges Edmond Ott, Percepteur des droits universitaires à Strasbourg, who in providing an audit of the accounts, has simplified the work of the Committee.

The Committee approves the suggestion of Prof. Rothé that the monthly salary of the administrative Secretary, Miss Schrapf, be increased, since it is too low.

(Signed) :

Dr. Markus Bath.
Prof. John H. Hodgson.
Prof. W. Hiller.

La séance est levée à 10 h. 45 m.

JEUDI, 16 SEPTEMBRE (après-midi)

Programme

16. Communications scientifiques : Mesures séismiques; Magnitude

1. — *M. N. Hill :* Velocity Measurements on Laboratory Samples of rocks.
2. — *M. N. Hill :* Seismic Refraction Shooting by the Sono-Radio Buoy Method in the Eastern Atlantic.
3. — *T. C. Gaskell :* Seismic Results obtained by H.M.S. Challenger in deep water.
4. — *M. Bath :* The Problem of Earthquake Magnitude Determination.
5. — *T. Asada, Z. Suzuki and Y. Tomoda :* On Frequency Distribution of Seismic Magnitude.
6. — *H. Kawasumi :* Intensity and Magnitude of Shallow Earthquakes.
7. — *K. Wadati* and *his Collaborators :* On the Magnitude of Earthquakes (especially of deep-focus earthquakes of short distance).

La séance est ouverte à 14 heures sous la présidence du *Professeur Gutenberg* qui demande aux orateurs de limiter à 10 minutes leur temps de parole.

16. Communications scientifiques : Ondes séismiques

1. — *Le Dr Hill* présente sa communication intitulée : Velocity Measurements on Laboratory Samples of Rocks.

Laboratory measurements have been made of the compressional wave velocity on 122 different rock samples. These measurements were made at atmospheric pressure, and after the rocks had been water saturated. The technique involved the direct measurement of the time taken for a short, high frequency pulse to travel through the rock. The frequency was 1 Mc/s and the thickness of specimen of the order of a few centimetres; the accuracy of the measurement was better than 1 per cent.

The results were shown in the form of histograms, which showed the following velocity ranges :

	Igneous			*Metamorphic*	*Sedimentary*	
Rock Type	Ultrabasic	Basic	Acidic		Lime-stones	Shales and Sand-stones
Velocity Range km/s	5.0-7.6	4.1-7.1	4.7-6.2	4.8-6.4	2.8-6.7	2.1-4.8

In the samples of the basic igneous rocks, in particular, there

seemed to be no direct association between the density and the velocity.

Results were also shown of the effect of compaction pressures on the compressional and shear wave velocities of finely divided chalk; these were remarkably similar to those obtained with deep sea calcareous oozes. The P wave velocity increased from about 1.5 km/s at atmospheric pressure to approximately 3.1 km/s at a pressure of 1,000 atmospheres. The S wave velocity over the same pressure range varied from about 0.6 km/s to approximately 1.5 km/s. On release of the pressure the P and S wave velocities decreased to 2.1 and 0.9 km/s respectively.

The technique and many of the observations were the work of Mr. A. S. Laughton.

Dr. F. Birch : The upper limit of velocity for a given rock is determined by the properties of the constituent minerals; this limit will be reached only when the minerals are in perfect contact with one another, or when the porosity is zero. Lower values of velocity are found for finite porosities : the velocity is sensitive to the porosity, and porosity in turn is sensitive to pressure. It is therefore to be expected that the range of velocity for rocks of similar compositions will be much smaller under pressure, with a closer distribution toward, or above, the highest velocities found at one atmosphere.

2. — Le *Dr Hill* présente une deuxième communication intitulée : Seismic Refraction Shooting by the Sono-Radio Buoy Method in the Eastern Atlantic.

The deep sea results obtained in expeditions in the North Atlantic by the sono-radio buoy method were described. Observations have been obtained from 21 different station positions between the latitudes of approximately 46° to 58° N, and lying between the bottom of the continental slope and the centre of the Mid-Atlantic Ridge. In the shallower water of the northern part of this area the velocities of compressional waves in the various layers were similar to those found in the deeper water, both in the Atlantic and in the other oceans of the world.

The restrictions of the method did not allow the depth to the Mohorovicic Discontinuity to be determined except in three positions where it lay between 9 and 13 km. The sediment thickness was approximately 0.5 km and this usually overlay a layer with a velocity of 4.5 km/s which was variable in thickness, being approximately 2.5 km thick in the deeper water, and up to approximately 4 km thick in the shallower water in the North of the area. This layer has been missed in earlier investigations and might be either a sedimentary rock or, possibly, a basaltic lava. Below this layer, and as far as the evidence indicates, extending to the Mohorovicic Discontinuity, the velocity of compressional waves is approximately 6.5 km/s, a value which is obtained from many deep sea stations elsewhere.

These results were, to a large extent, obtained by Mr. J. C. Swallow.

The final papers by Dr. M. N. Hill are intended for publication in the « *Proceedings of the Royal Society* ». The preliminary infor-

mation on some of the refraction shooting results have, however, been published : Seismic Observations in the Eastern Atlantic by M.N.Hill and A.S. Laughton, Proc. Roy. Soc. A *222*, 348-356, 1954 (2 figs.)

Dr. *Revelle :* Dr. R. W. Raitt has found in at least 80 % of his seismic refraction stations in the deep Pacific a layer ranging at different stations from less than one to more than two kilometres in thickness and in velocity from 4.5 to 5.3 km/sec. This was determined from first arrivals. Above it he finds a layer of presumably unconsolidated sediments 0.1 to more than 1 km thick, and below it a layer usually more than 5 km and less than 10 km thick with a velocity usually about 6.7 to 6.8 km/sec., immediately above the Mohorovicie discontinuity (velocities of 8 or more km/sec.). He has found velocities, of about 4.5 km/sec. under the island shelves off Hawaii, the Marquesas and Guadelupe Island. He also finds about the same velocity on Eniwetok and Bikini atolls at depths of about 4000 feet, corresponding to the depth at which basalt was recovered from the drill hole at Eniwetok. I personally find it difficult to understand any mechanism of sediment consolidation which could result in a sharp discontinuity of velocity at depths as well as 100 meters below the sea floor, which would be required to explain the 4.5 to 5.3 km/sec. layer as consolidated sediment.

3. — Le *Dr Gaskell* présente sa communication : Seismic results obtained by H. M. S. Challenger in deep water.

H. M. S. Challenger made a round the world voyage lasting for $2\frac{1}{2}$ years, and in the course of steaming 75,000 miles, mostly in the Northern hemisphere, new facts of submarine geology were collected in the Atlantic, Pacific, and Indian oceans. The sea bed in deep flat ocean areas is different from that on continents, and consists of a layer of low-velocity sediment about 0.3-1.5 km. thick resting on a material in which the compressional wave velocity is 6.4-6.9 km/sec. There is some evidence that the lower part of the sediment layer is consolidated. Near islands and atolls a thick layer of 4.5 km/sec. material indicates that volcanic material has errupted and has subsequently sunk to form a depression of the 6.4-6.9 km/sec. layer. A reasonable explanation is therefore provided for the three main topographic features of deep permanent ocean basins : volcanic islands, atolls and sea mounts.

An account of part of the work by T. F. Gaskell has been published in « *Proc. Roy. Soc. A.* », Vol. 222, pp. 356-361, 1954.

MM. *Birch, Hill* et *Revelle* prennent part à la discussion.

4. — *Dr M. Bath* presents his paper: The Problem of Earthquake Magnitude Determination.

The magnitudes of a number of earthquakes have been determined by means of P, PP, S and the surface waves recorded at Uppsala and Kiruna during the years 1952 and 1953. The various determinations have been compared with each other in different ways and also with determinations made at other stations. Large differences found for a particular wave compared to the other waves or for particular earthquake regions in comparison with determinations at other stations have been specially studied. All differences have very clear geographical distribution. There is much less scatter in the magnitude differences between Uppsala and Kiruna for the

surface waves than for body waves. The magnitude differences between body waves and surface waves have been put in relation with the focal depth. These relations agree numerically with theoretical expectations except for the case when the body wave used is short-period P, where the variation with focal depth is about twice as large. The reason for this is the relatively greater importance of short-period P for the deeper foci. Both from magnitude relations and from the existence of sharp pP it is obvious that there are many more foci slightly deeper than normal than usually believed. From the comparison of Uppsala and Kiruna it is clear that local conditions in the vicinity of the recording station are of great importance for the amplitudes obtained. For instance, the ratio of amplitudes of different waves determined from the records at a single station is completely masked by the local conditions. Finally, some suggestions are made to improve the accuracy of the magnitude determinations by a combination of the different waves.

Le texte complet de la communication du Dr. Bath est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques, fascicule N° 19.*

Prof. Gutenberg : The magnitudes resulting from the calculations are in better agreement than it had been expected. For more accurate results using P and S the azimuth towards the station and the angle of incidence have to be introduced. In the main Kern County' California shock of 1952 the magnitude of the surface waves was a function of azimuth. The relationship between Magnitude M and energy E used at present at Pasadena is log. $E = 11 + 1.6\ M$.

Dr. Tsuboi asked if Dr. Bath is quite sure that the apparent difference in magnitude which he has shown is due to something at the origin rather than to something at the observation station.

Dr. Tsuboi continued : I have determined the following formula for calculating M from $\triangle$ (km) and A (max. ground amplitude in micron) :

$$M = 1.73 \log \triangle + \log A - 0.83$$

This is an average formula applicable to most Japanese stations for most Japanese earthquakes. But if the formula is determined for each of the stations separately, the constants in the formula are seen to differ considerably from station to station, as follows :

Sapporo	$M = 1.99 \log \triangle +$	$\log A$	$- 1.62$
Sendai	1.22		$+ 0.52$
Tokyo	1.55		$- 0.46$
Nagoya	2.48		$- 2.90$
Kobe	2.00		$- 1.39$
Fukuoka	1.48		$- 0.17$

There are indications that the difference in these constants is related to that in the underground structure beneath the stations.

Prof. Gutenberg : The magnitudes calculated in Japan include the difference between the assumed and the actual instrumental constants which differ from station to station.

5. — Le *Professeur Wadati* présente une communication de MM. *T. Asada, Z. Suzuki* et *Y. Tomoda* sur la distribution de la fréquence des magnitudes des séismes.

Plusieurs spécialistes ont déjà étudié la distribution de la fréquence des magnitudes des séismes. Mais ces études concernaient des séismes qui avaient eu lieu dans des régions diverses et les statistiques qui ont pu être dressées étaient basées sur des échelles de magnitude différentes.

Comme les relations entre ces échelles de magnitude sont connues nous avons essayé de rendre comparable par la méthode des transformations des variables les résultats des études précédentes.

Nous avons trouvé que dans tous les cas étudiés la même forme de distribution de fréquence est applicable. On peut écrire :

$$N(M)\,dM = \text{const.}\ 10^{-0,9\,M}\,dM$$

Ce fait est à noter pour les études sur le caractère physique de l'écorce terrestre.

Nos recherches faites avec des instruments de haute sensibilité montrent aussi que cette formule reste applicable même pour un séisme très faible dont la magnitude est comprise entre 1 et -1.

L'énergie d'un séisme dont la magnitude est -1 est à peu près 10^{10} ergs.

Ce séisme est le plus petit de ceux qui ont pu être jusqu'à présent enregistrés de façon certaine au Japon.

Par ailleurs l'application de cette formule a des limites.

Nos études statistiques ont montré que la dimension de la zone sismique à laquelle un séisme appartient détermine les limites dans lesquelles la formule peut être appliquée.

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques, fascicule N° 19.*

6. — Le *Professeur Wadati* présente la communication de *M. H. Kawasumi* : Intensity and Magnitude of Shallow Earthquakes.

The intensity of an earthquake at a point depends on the magnitude and the distance of the point from the hypocentre of that earthquake. It also depends, as is well known, on the subsoil conditions of the point of observation and the direction (azimuth and colatitude) of the point from the origin owing to the mechanism of the earthquake occurrence. In addition to these factors, there is some indication that crustal structure along the path of the seismic wave also plays an important role in this connection. The hypocentral depth of the earthquake thus influences the intensity distribution on the earth's surface from two sides, of which the first is the distance effect and the second the dissipation which seems to vary with the depth from the surface.

Critical examination of the effects of these factors are being undertaken by the writer with the restriction, for the present, to the case of shallow earthquakes.

Mean intensity-distance ($I - \triangle$) and ground amplitude distance ($A - \triangle$) curves of ca. 200 earthquakes of shallow origins in Japan were derived and formulae to determine the Richter-Gutenberg magnitude were shown. Mean anomalies of $I - \triangle$ and $A - \triangle$ for each station were derived. These mean anomalies are the station corrections arising from the subsoil conditions.

Effects of subsoil conditions on the intensity at a point are then discussed from observations of unaided senses and severity of damages. Relations between the magnitude and the total damages for Japanese earthquakes are also determined.

Le texte complet de la communication de M. H. Kawasumi est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques, fascicule N° 19.*

7. — *Le Professeur Wadati* résume sa communication : Sur la Magnitude des séismes, principalement des séismes à foyer profond à courte distance (1).

1. Notre expérience montre qu'il est très difficile de déterminer exactement la magnitude (d'après la définition de Richter-Gutenberg) des séismes à courte distance, particulièrement de ceux à foyers profonds, au moyen des observations de l'amplitude du mouvement du sol en une station ou en plusieurs stations. La cause principale en est que, en cas d'un séisme à courte distance, la complexité et l'irrégularité de la couche de Mohorovicic et de la couche supérieure du manteau exercent sur la propagation des ondes séismiques une influence plus importante que dans le cas d'un séisme éloigné; l'absorption des ondes séismiques à courte période est beaucoup plus grande.
2. Quant à la structure de la couche supérieure du manteau, nous avons constaté, d'après les observations des séismes à courte distance, particulièrement d'après la relation entre l'amplitude et $\triangle$, qu'une couche de petite vitesse (surtout concernant l'onde S) existe, semble-t-il, sous la terre du Japon et de son voisinage à la profondeur d'environ 100 km. et aussi vers 300 km. de profondeur.
3. Bien qu'il soit désirable de considérer la complexité de la structure de la couche de Mohorovicic et de la couche supérieure du manteau, nous avons ici négligé cela, en première approximation, et nous avons cherché à obtenir l'absorption des ondes séismiques en supposant que, sous terre, la vitesse de l'onde séismique est une fonction de la profondeur seulement et augmente avec la profondeur; nous avons obtenu les coefficients d'absorption des ondes séismiques à diverses profondeurs, résultats qui pourront expliquer la relation entre l'amplitude observée dans un séisme à foyer peu profond et $\triangle$.
4. En employant les coefficients d'absorption obtenus au paragraphe 3, on a calculé l'absorption le long des trajectoires des ondes séismiques, et la courbe-standard (amplitude — $\triangle$) pour chaque profondeur de l'hypocentre.
5. Nous donnons comme exemple une méthode qui permet d'obtenir la magnitude des séismes à courte distance au voisinage du Japon en faisant usage de la courbe standard (amplitude — $\triangle$) mentionnée au paragraphe 4.

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(1) This investigation was made with the collaboration of earthquake researchers of the Central Meteorological Observatory, Tokyo, namely Wadati, Inouye, Hirono, Suyehiro and Usami. The theoretical calculation was made chiefly by Hirono.

Le texte complet de la communication ci-dessus doit paraître prochainement dans « *Geophysical Magazine* » (publication du Central Meteorological Observatory, Tokyo).

M. *E. Peterschmitt* rappelle qu'il a été décidé à Stuttgart en 1952 d'établir un catalogue des séismes européens. Pour chaque séisme il faudrait indiquer si possible la magnitude. Un travail de calcul de la magnitude a déjà été exécuté par MM. Di Filippo et Marcelli pour des séismes italiens. Ce travail devrait être étendu aux séismes européens en s'appuyant sur les inscriptions fournies par des appareils se rapprochant autant que possible des séismographes à torsion. Les seuls appareils remplissant cette condition semblent être les séismographes à grande masse (15 à 20 tonnes) et de période propre de 1 à 2 secondes.

8 stations européennes seulement sont dotées d'appareils de ce type. Afin d'arriver à des résultats définitifs une étroite collaboration européenne est nécessaire. La définition instrumentale de la magnitude peut être établie pour les 25 dernières années. Il faudra ultérieurement chercher une relation magnitude-éléments macroséismiques, afin de pouvoir faire le calcul pour les tremblements de terre anciens.

La séance est levée.

CINQUIÈME SÉANCE

VENDREDI, 17 SEPTEMBRE (matin)

Programme

16. — Communications scientifiques : Ondes séismiques.

8. — *Sir Harold Jeffreys :* The Travel-Times of P.

9. — *I. Lehmann :* The Velocity of P and S Waves in the upper part of the Earth's mantle.

10. — *J. Cl. De Bremaecker :* Observations of the Amplitudes of Pn from 3° to 23°.

11. — *Fr. Press* and *M. Ewing :* Pn and Sn Velocities at large distances.

12. — *P. Caloi :* Onde longitudinali e trasversali guidate dall' astenosfera.

*12*bis. — *P. Caloi :* Les ondes Ci, j, associées aux S(V), SS... PS... et la structure de la croûte terrestre.

13. — *V. Kárnik* et *J. Vanek :* Travel-Times of the principal Seismic Waves for Praha .

14. — *E. Peterschmitt :* Quelques anomalies de l'inscription du séisme du Pérou du 12 décembre 1953.

La séance est ouverte à 9 h. 15.

16. Communications scientifiques : Ondes séismiques

8. — *Sir Harold Jeffreys* reads his paper : The Travel-Times of P.

In the construction of the Jeffreys-Bullen tables of 1940 several discrepancies were found of the order of a second or two. The apparent standard errors of the times of P were about 0.3 to 0.6s, but in view of the occasional discrepancies, apparently a little too large to be attributed to random errors, it was uncertain how generally applicable the tables were. What was clear was that no single set of tables would fit all earthquakes better. The exceptional data at that time were capable of several interpretations.

In the Burton-on-Trent explosion P arrived at 8° about 4s early in comparison with the table for a surface focus, the origin time being found from near observations, and this led me to reexamine the data. In Europe the information about the velocity of P at short distances came mainly from near earthquakes, and of these the Tauern and Schwadorf earthquakes, studied by Conrad, gave values with much lower apparent uncertainties than any of the others; but these values disagreed. In Japan there were many lists of observations of small earthquakes well observed at short distances, and the Tauern velocity agreed with them; hence it seemed best to take this as general.

The anomalous observations in the Burton explosion suggested that this was wrong. I therefore reexamined the original near earthquake data and several more recent studies. These fully confirmed the suspicion. The table corresponds to $dt/d\triangle$ at short distances $=$ 14.3 s/1°; the correct value is 13.73 $\pm$ 0.13 s/1°. The corresponding velocities are 7.8 and 8.1 km/sec (1). The result was confirmed immediately by Willmore's study of the Heligoland explosion (2).

The small Japanese earthquakes were therefore examined afresh, with particular reference to the possibility that P might have been read late owing to weakness. Doubtful ones were excluded, but the rest fully confirmed the original value; there is a definite systematic difference between Japan and Europe (3).

It was therefore desirable to see whether there were corresponding differences at other distances. At first I attended to distances up to 30°. The advantage of this range is that a small error in the epicentre would affect the times at all stations in the same quadrant by nearly the same amount; consequently each quadrant would give us useful independent equations for the differences of times at different distances. This was very important because many earthquakes have only a few near observations except near one or two azimuths, and would have to be rejected altogether if uncertainty of the epicentres made much difference to the solution.

The times to 30° were thus found. For greater distances the principle of quadrants is not applicable, and the epicentres had to be redetermined from observations within 30°. Only 6 Japanese and

(1) H. Jeffreys, M. N. Geophys, Suppl. 5, 1946, 105-119.
(2) P. Willmore, Phil. Trans. Roy. Soc. A., 242, 1949, 123-151.
(3) H. Jeffreys, M. N. Geophys. Suppl. 6, 1951, 348-364.

5 European ones turned out to be useful (4). These were enough to test some important points. The problem is similar to that of seismic prospecting, but on a worldwide scale. It might be expected that there would be a difference of times in Japanese earthquakes according as the paths were under the Pacific or under Eurasia . When residuals over corresponding ranges of distance were compared, however, the difference was only 0.3 ± 0.5s and not significant. As this is the largest structural difference that we know of, it seemed that the regional differences of structure are confined to moderate depths. Times in European earthquakes to Japan and North America also showed no systematic difference. There was some evidence for a slight difference between the Eastern and Western halves of Eurasia, but it was not conclusive. Separate travel time tables were made for European and Japanese earthquakes.

North American earthquakes added very little information. The difficulty is that the stations usually fell near only one or two azimuths, and the ranges of distance in these did not overlap. Thus the epicentres could always be adjusted to hide an error in the table.

The corrections to the present P table for a surface focus run as follows. The range 10° to 20° was taken as standard and the other uncertainties are in comparison with it. Comparison of European observations of Japanese earthquakes with Japanese ones of European earthquakes permitted an adaptation of Japanese earthquakes to a surface focus, but this comparison has an uncertainty of ± 1.0s, which affects the whole table for Japanese earthquakes equally.

	European	Japanese
0	+0.9±0.7	—0.3±0.3
5	—2.0	0.0±0.3
10	—3.0	—0.2±0.3
15	—2.3	—0.3±0.3
20	—3.8	—2.1±1.0
25	—2.3	—1.4
30	—1.6±0.3	—1.8±0.7
40	—1.0±0.7	—1.8
50	—1.0±0.5	—1.9
60	—0.7±1.4	—1.4±0.7
70	—1.1±0.5	—0.9±0.5
80	—1.7	—1.1±0.5
90	—1.2±0.7?	—1.2±0.6

The time in Europe is nearly a linear function of distance up to 15°, but in Japan there is a definite curvature. The former would agree with Gutenberg's idea of a low-velocity layer, though I find the American earthquakes insufficient to establish this. In any case it was always rather difficult to understand why the curvature was so small, since the laboratory variation of compressibility with pressure suggests a much stronger curvature. Something must cancel the greater part of the effect of pressure on velocity, and the data available to me suggest that temperature is inadequate unless the temperature gradient is much larger than anybody has yet supposed.

(4) H. Jeffreys, M. N. Geophys. Suppl. (in the press).

The curvature remains strongest about 20°, but the data do not suffice to decide whether the gradient is really continuous there or whether the phase is triplicated. More special studies similar to that carried out by Miss Lehmann (5) are greatly needed.

Prof. Gutenberg : This paper is of great importance. The velocity of Pn was first to be 7.8; then from explosion seismology the velocity 8:1 was found. This result was then confirmed by earthquake results. The same result has now been found in Japan. It is suggested that a channel wave is responsible for the original low velocity. This might be due to the effect of temperature : the scanty data, most of them by Birch, suggest that the effect of pressure and temperature might compensate each other down to about 10 km. and that below 10 km. the velocity might decrease.

Prof. H. Jeffreys questions this opinion.

Dr. Birch : If the composition of the layer is uniform, then it is possible that a low velocity layer would occur, but if the composition of the layer varies, then nothing can be said.

Prof. Bullen : In New Zealand the observations are affected by errors so great that no conclusions can be drawn so far.

Prof. Gutenberg : The reasons for the greater velocities found in explosion seismology are that the distance of observation is limited to about 5° and that short period very sensitive instruments are used. On the other hand from earthquake records it is difficult to find the accurate velocity of Pn because few stations use highly sensitive vertical instruments and the beginning of records taken at a distance over 5° is usually a phase later than Pn.

9. — *Miss Lehmann* then presents her paper : The Velocity of P and S Waves in the upper part of the Earth's mantle.

The velocity below the Mohorovicic discontinuity is now known to be about 8.15 km/sec. Correcting the J-B curve, H. Jeffreys finds the P time-curve for Europe to be a straight line up to 15°.

A trial solution has been made for v(r) in the upper mantle. Vp is taken to increase strongly at first, the deepest ray emerging at 5°. Below, down to 200 km depth, Vp is taken to increase slowly and lower down to increase strongly again. The P time-curve then forms a loop which comes close to the first branch. The times of the first phases are in agreement with the corrected J-B times up to 22°.

Vs is taken to decrease slowly in the layer in which V_p increase slowly and to increase in the same ratio as V_p in the other layers. The S time-curve then forms a very long loop having the lower cusp 21^s above the first branch. This is about the delay of the late S phases as observed. Very little energy would be associated with the points of the extended forward branch and so amplitudes would be negligible, as in reality they are. In earlier investigations I found the late S points to lie close to lines that would form part of loops similar to the one calculated.

With Vp increasing and Vs decreasing in the same layer, the rigidity would decrease relative to the compressibility and to the density. Thus the compliance of the material may be said to be increased. Poisson's ratio is increased and since it does not seem to decrease lower down in the mantle, the whole of the increase of

(5) I. Lehmann, Medd. Geod. Inst. Köbenhavn, 5.

compliance seems to take place in quite a thin layer near its upper boundary.

In California Vp, as well as Vs, decreases, but Vs probably more strongly than Vp, so that here again the compliance increases in a thin layer.

In N. E. America, S observations differ distinctly from those of Europe and California, the early « true » S being well observed up to 14°. At that distance there is a break in the S curve and all later S are delayed. So here again there is a layer in which the compliance increases, but it is at a greater depth.

Thus there are regional differences in the upper mantle, but in all the regions considered there is a thin layer in which Vp and Vs vary but little with depth, and there is an increase of compliance of the material.

La communication de Mlle Lehmann est destinée à être insérée dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques, fascicule N° 19.*

Prof. Bullen : An Earth model which I have constructed on the basis of smooth variation of compressibility with depth at great depths in the Earth suggests that the level at which the 20° discontinuity occurs is appreciably above a depth of 400 km. This suggestion appears to be in line with implications of Miss Lehmann's work.

10. — Dr. J.-Cl. De Bremaecker présente sa communication : Observations of the Amplitudes of Pn from 3° to 23°.

Gutenberg's method of plotting amplitudes was used unsuccessfully on twelve seisms. A combination of the results of each seism in limited ranges of distance proved satisfactory although the scattering was large. The theoretical explanation proposed is that the curve results from a combination of the « refracted » rays (amplitude decreasing as $1 / \triangle^2$) and of the ordinary rays. The intersection of these two curves yields the small amplitudes observed around 8° whereas a « relatively low velocity layer » is responsible for the gradual decrease in the amplitudes beyond 14°.

Le texte complet de la communication ci-dessus a paru en langue anglaise dans « *Bulletin of the Seismological Society of America* », vol. 45, N° 3, 1955, pp. 219-244, 18 fig.

Dr. Wadati : It is important to consider the effect of absorption in the earth when investigating the nature of the low-velocity layer from the data of amplitude observation. And for the investigation of low-velocity layer in the upper mantle, I think that intermediate and deep-focus earthquakes may give more usable data than shallow ones do. But I think it is very difficult to separate the effect of the absorption from that of the divergence.

MM. *Birch, Bullen* et *Gutenberg* prennent également part à la discussion.

11. — Dr. Frank Press reads the paper of Messrs. *F. Press* and *M. Ewing :* Pn and Sn Velocities at large distances.

Waves having velocities close to Pn and Sn have been observed on the Columbia University long period seismographs at epicentral distances of 50°—125°. Their characteristics are described and a

mechanism of propagation is suggested involving numerous multiple reflections (whispering Gallery) at near-grazing incidence from the underside of the Mohorovicic discontinuity.

The complete text of this paper is intended for publication in the « *Proceedings of the National Academy of Sciences* », probably in Volume 34, N° 1, Januar, 1955. There are four figures.

12. — *Le Prof. Caloi* présente sa communication : Onde longitudinali e trasversali guidate dall'astenosfera.

Dans une brève note, ayant ce titre présentée à l' « Accademia Nazionale dei Lincei » en novembre 1953, le Prof. Caloi avait annoncé l'existence d'ondes séismiques longitudinales et transversales, guidées par l'asténosphère. Les tremblements de terre ayant leur origine au-dessous de la croûte terrestre, et à des profondeurs allant jusqu'à 300 km, engendrent des ondes élastiques des deux types, qui se propagent dans la couche sphérique ainsi délimitée (ondes indiquées avec les symboles Pa, Sa).

L'origine de ces ondes doit être recherchée dans la partie de l'énergie séismique qui est guidée dans le canal asténosphérique, où se vérifie une courbure dans la courbe des vitesses.

Pour la première fois l'existence d'un épais canal guide d'énergie séismique dans l'intérieur de la Terre était ainsi prouvée.

Ici on apporte de nouveaux et nombreux exemples des ondes Pa, Sa, enregistrés pour des distances épicentrales variant entre 2.000 et 18.000 km environ.

L'asténosphère conduit même des ondes de type Rayleigh (Ra).

Le phénomène, naturellement, prend un caractère général, en ce sens que des couches où l'on observe des diminutions de vitesse peuvent guider des ondes séismiques.

Le Professeur Caloi rappelle que le Professeur Gutenberg dans son adresse présidentielle a approuvé l'hypothèse qu'il a lui-même avancée dans une communication à l'Académie des Lincei. M. Caloi avait constaté que certaines ondes n'apparaissaient nettement que lorsque le séisme se produisait entre 50 et 300 km. Le premier groupe avait une vitesse presque constante de 8,2 km et le 2e groupe une vitesse de 4,4. On peut suivre ces groupes de 3.000 à 18.000 km. La vitesse de propagation est celle au-dessous de la croûte terrestre et l'origine des séismes doit être dans cette même région.

Lorsqu'un tremblement de terre a son origine entre 50 et 120 km les conditions sont réalisées pour qu'une partie plus ou moins grande d'énergie se propage dans l'asténosphère qui fait alors fonction d'un canal guide.

M. Caloi cite l'exemple du tremblement de terre du Turkestan du 2 novembre 1946 dont la profondeur est d'environ 70 km et qui présente clairement les ondes Pa et Sa.

M. Caloi cite encore l'exemple du séisme du 10 novembre 1953 (enregistrement à Tamanrasset et enregistrement à Tucson de l'onde Sa sur une composante verticale).

Dans un tel cas, les phases PP et PPP doivent être très faibles. Les rayons sont captés par l'asténosphère et pour certaines distances épicentrales, il ne doit y avoir que des traces d'ondes PP et PPP. M. Caloi cite l'exemple du séisme du 22 juillet 1953 inscrit sur la composante verticale à Kiruna.

Un examen plus approfondi de ces ondes doit permettre d'étudier les propriétés de l'asténosphère et de la croûte terrestre.

La communication du Prof. Caloi a été publiée sous le titre « L'astenosfera come canale-guida dell'energia sismica » dans « *Annali di Geofisica* », Vol. VII, N° 4, 1954, pp. 491-502, 17 figs.

M. *De Bremaecker* demande comment de telles ondes peuvent apparaître à la surface ?

Le *Prof. Caloi* répond que les ondes Pa ayant une période moyenne de 8 sec., leur longueur d'onde est voisine de 100 km. L'épaisseur de la croûte étant de 30 km., ces ondes peuvent alors apporter de l'énergie à la surface du sol.

Prof. Gutenberg : This paper is only a start but opens a whole new group of problems. The waves observed by Caloi and by Press need not be body channel waves but could possibly be a type of «surface» channel waves for which we have no theory. In all these observed waves the vertical component is relatively large and the maxima of the horizontal components are not simultaneous with those of the vertical. Since the depth of the low-velocity channel is only about two wave length below the surface of the earth, the observation of the waves at the surface would be no objection to Caloi's explanation. On the other hand, the waves Pa and Sa have relatively large a...plitudes, whereas Pn and Sn are small waves and it is difficult to see how large amplitudes could result even by a « whispering gallery » effect.

Dr. Stoneley : Many years ago Sir James Jean proved that both compressional and distortional waves should be propagated round the surface of a sphere by what is equivalent to the limit of repeated reflexions, but I believe that Sir Harold Jeffreys estimated that only a small fraction of the energy travels right round the sphere. It is interesting that Dr. Press has discovered waves of this type : has he been able to examine records of a number of deep-focus shocks where one might expect the true surface waves of Love type to be suppressed, leaving the « whispering gallery » type of S-wave ? The times of travel of PPP, PPPP, SSS, SSSS, etc. are not very different, of course, from what would correspond to a superficial wave with velocity equal to that of Pn or Sn near the surface.

Prof. Gutenberg : Prof. Caloi has given evidence for deep shocks.

Prof. Benioff : As far as the difficulty of existing of these waves is concerned, one should note that the extent of the depth of faulting is important.

Dr. Bath : Why are there no observations at distances less than 50° ?

Dr. Press : Because at smaller distances these waves coalesce with others.

Dr. Bath : It would be interesting to examine the amplitudes of these Pn and the ratio Pn/Pa. There is a small error of date in one shock : 1954 should be replaced by 1953.

Prof. J. T. Wilson : There is a difference in time between Sn and Sr_3 or Sr_4 at 40° . . . 50°. There are S reflexions at the beginning of Love waves. Also often vertical and horizontal components are different because of the difference in reflexion between SH and SV.

Dr. Press : It should be understood that grazing incidences are required. The pulse character is also an indication of « whispering gallery ».

Dr. Baxter : What is the reason for the difference in amplitude between the components ?

Dr. Press : The data are as yet insufficient to settle all the issues.

*12*bis. — « Les ondes Ci, j, associées aux S(V), SS..., PS... et la structure de la croûte terrestre », par *P. Caloi.*

Il y a déjà plusieurs années (1933) l'attention a été attirée sur l'existence de systèmes d'ondes séismiques, associées aux ondes S, SS..., PS... Dans un travail datant de 1948, j'ai donné l'explication suivante sur la nature de ces types particuliers d'ondes : elles sont provoquées par le choc des ondes SV à la base des couches de la croûte terrestre, sous condition cependant que l'angle d'incidence de l'onde SV soit plus grand que l'angle critique.

Selon que l'angle critique est atteint à la base du « granit », de la couche intermédiaire ou de la croûte terrestre, nous aurons des ondes Ci, j de diverses périodes : en moyenne, dans le premier cas la période est de 24s, dans le second de 35s et dans le troisième de 50s. Les distances épicentrales auxquelles les trois types d'ondes considérés commencent à paraître sont de l'ordre de 3.000 km pour les $C_{2,1}$, de 4.000 km pour les $C_{1,1}$ et de 6.500 km pour les $C_{0,1}$.

Des ondes du même type pourront aussi apparaître à des distances multiples de celles qu'on vient d'indiquer, c'est-à-dire en correspondance des ondes SS (auxquelles seront associées, respectivement, les $C_{2,2}$, les $C_{1,2}$ et les $C_{0,2}$), ou des SSS (avec création des ondes $C_{2,3}$, $C_{1,3}$ et $C_{0,3}$).

Leurs périodes sont liées aux épaisseurs des couches de la croûte, sous lesquelles se produit la réflexion sous l'angle critique.

Les ondes Ci, j sont analogues aux ondes évanescentes considérées par la théorie dans le cas de réflexion sous l'angle critique. On démontre cependant qu'elles dépendent des surfaces internes de discontinuité de la croûte de sorte que l'angle critique peut être atteint par les ondes incidentes; cela est aussi témoigné par la pluralité des ondes Ci, j, pluralité qui n'aurait pas de sens si elles tiraient leur origine de la surface extérieure de la Terre.

Les Ci, j ont toutes les caractéristiques des ondes évanescentes : par leur origine, par leurs périodes, par les mouvements elliptiques qu'elles impriment aux particules par elles rejointes. Comme dans le cas de la lumière, même pour les Ci, j, il est possible d'individualiser des trains d'ondes stationnaires correspondant à l'interférence d'ondes évanescentes qui se propagent dans les deux sens, avec une vitesse de l'ordre de celle considérée par la théorie.

Toutes choses égales d'ailleurs, l'amplitude et la période de ces ondes sont d'autant plus grandes que la station séismologique qui les enregistre est plus continentale.

La communication du Prof. Caloi est destinée à être publiée en langue italienne dans « *Annali di Geofisica* ».

13. — La communication de MM. *V. Kárnik* et *J. Vanek:* « Travel-Times of the principal seismic Waves for Praha » est déposée sur le bureau.

In order to investigate the reliability of existing travel time tables for a single station and to study eventual local or regional effects on the transmission of bodily seismic waves local travel time curves of P, PP, S and SS waves were constructed by a numerical method for the station Praha. A sufficient set of observations was obtained from the records of Wiechert horizontal seismograph for the period 1930-1948. All records were remeasured independently by two investigators so that for every phase two independent readings existed and an unprejudiced classification was possible. As sources of earthquake parameters the International Seismological Summary for 1930-42 and Gutenberg-Richter's « Seismicity of the Earth » for 1943-48 were used. Only shallow shocks / $h < 50$ km/ were investigated. Three partial sets based on three different travel time tables /ISS1 for 1930-36, ISS2 for 1937-42, GR for 1943-48 were reduced to the ISS2 set so that a homogeneous body of observations was obtained. Corresponding epicentral distances and azimuths were determined numerically or graphically with sufficient precision. The travel time curve for P and S waves was approximated by a polynomial $T_1(\triangle)$ of the third degree without square term for $10^\circ < \triangle < 20^\circ$ and $T_2(\triangle)$ of the second degree for $20^\circ < \triangle < 105^\circ$, coefficients of which were fitted by least squares with a condition $T_1 = T_2$ for $\triangle = 20^\circ$. Similary for PP and SS a quadratic $T'_1(\triangle)$ at distances $\triangle < 40^\circ$ and $T'_2(\triangle)$ at $\triangle > 40^\circ$ were used with a condition $T'_1 = T'_2$ for $\triangle = 40^\circ$. Standard errors were determined and the results compared with mean travel time tables by Jeffreys-Bullen, Gutenberg-Richter and local travel time tables for Uppsala, Zagreb and Hamburg. In the interval $20^\circ < \triangle < 105^\circ$ the travel time curves for Praha approach in their form to Jeffreys-Bullen travel times passing between those for surface focus and those for 0.00R. This phenomenon appears at all existing European local travel time curves. In the interval $10^\circ < \triangle < 20^\circ$ the travel time curves for Praha have a completely different course in comparison with all other travel times; this was explained by regional effects typical for the eastern Mediterranean and Asia Minor. The deviations O - C do not depend perceptibly on azimuth and epicentral distance. By the investigation of eventual regional distribution of O - C deviations a systematic distribution of negative deviations was found only for Japan and Kamchatka; the average $-2{,}0^s$ for P agrees reasonably with $-2{,}2^s$ observed at Hamburg for the same region. A further study of local travel time curves constructed by a uniform method for several near stations /e.g. for European stations/ could be interesting and important.

Le texte complet de la communication a paru sous le titre « Travel Times of P and S Waves for Praha » par V. Kárnik et J. Vanek dans les « *Travaux de l'Institut Géophysique de l'Académie Tchécoslovaque des Sciences* », N° 16, 1954, pp. 107-157.

14. — M. *E. Peterschmitt* présente sa communication : Quelques anomalies de l'inscription du séisme du Pérou du 12 décembre 1953.

Le premier dépouillement à Strasbourg du séisme indiqué a montré la présence d'une anomalie notable; les ondes PP semblent arriver

avec une avance de 20 secondes environ. L'étude des nombreuses inscriptions mises à ma disposition a montré qu'il était possible de distinguer entre des distances épicentrales de 87° et 105° deux ondes : une onde PP normale dont les temps de propagation correspondent aux tables de Jeffreys-Bullen, et une onde anormale qui la précède. Entre 105° et 120°, cette onde se place entre les P et les PKP. Il est probable que cette onde est identique avec l'onde K de Gutenberg et Richter (On Seismic waves, first paper) interprétée par ces auteurs comme une onde diffractée.

Tandis que l'inscription des ondes P dans les stations américaines révèle l'existence de deux impétus, toutes les stations européennes ne montrent qu'un seul impétus. On se trouve certainement en présence d'un mécanisme au foyer compliqué, mécanisme qui est peut-être aussi à l'origine de l'onde anormale observée.

Prof. Gutenberg : There are many other phases that exist and one new idea may explain many phases.

La séance est levée à 12 h. 15 m.

SIXIÈME SÉANCE

VENDREDI, 17 SEPTEMBRE (après-midi)

Programme

Séance commune avec l'Association d'Hydrologie, section neige et glaciers.

Communication scientifique : Etudes séismiques sur l'Inlandsis du Grœnland.

La séance est ouverte à 14 heures.

15. — M. *J.-J. Holtzscherer* présente les résultats séismiques obtenus au Grœnland par les expéditions polaires françaises.

De 1949 à 1952, la section de sondages séismiques des Expéditions Polaires Françaises a effectué des mesures au Grœnland afin de déterminer l'épaisseur de l'Inlandsis sur différents profils et d'obtenir des renseignements sur la nature et la forme du terrain sous-glaciaire.

Les vitesses de propagation des ondes séismiques dans la glace et dans le substratum rocheux furent déterminées par l'emploi de la méthode de réfraction, tandis que pour les mesures de l'épaisseur de glace, la méthode de réflexion a été utilisée.

Les vitesses de propagation dans le milieu névé-glace varient de 3.800 à 4.000 m./s. Il semble exister une relation entre la valeur de ces vitesses et la température du milieu. Sous la glace, deux couches de terrain rocheux ont pu être identifiées. La première couche pré-

sente une épaisseur d'environ 250 à 300 m. et admet une vitesse de propagation de 4.800 à 5.000 m./s., la deuxième couche admet une vitesse de propagation de 5.450 m./s. au Camp VI et de 6.000 m./s. au Camp IV. Une couche à grande vitesse (6.650 m./s.) a également été trouvée au Camp VI.

Les épaisseurs de glace sont connues pour près de 400 points répartis sur plusieurs profils dans la moitié Sud et sur un profil Ouest-Est dans la partie Nord de l'Inlandsis. Ces données ont permis de tracer plusieurs coupes de l'Inlandsis. Les deux coupes Ouest-Est tracées pour la partie Nord et pour la partie centrale de l'Inlandsis font ressortir la forme en cuvette du substratum rocheux dont le fond plat se trouve au niveau de la mer $\pm$ 200 m. près. La partie Sud du Grœnland se présente sous forme d'un plateau qui se maintient à une altitude de 1.000 m. On a tenté d'établir une carte du relief sous-glaciaire et d'évaluer le volume de l'Inlandsis, dont la valeur trouvée est de $2{,}7 \times 10^6$ km^3.

Les résultats complets ont été publiés sous le titre : A. Joset et J. J. Holtzscherer, Sondages séismiques au Grœnland. *(Ann. de Géophysique,* Paris, tome 9, 1953, pp. 329-344 et tome 10, N° 4, 1954, pp. 1-31.)

Prof. O. Vecchia : Puisque l'orateur a laissé ouverte la question de la nature des couches sousglaciaires ayant une vitesse de plus de 6 km./sec., il n'est peut-être pas inutile de rappeler que, pendant des mesures séismiques de réfraction sur le versant italien du Mont-Blanc, on a mesuré une vitesse de 7.100 mètres-sec. dans des gneiss anciens. Ainsi il n'est pas justifié de poser l'équation vitesse élevée = basalte.

M. Holtzscherer demande si ces profils de réfraction ont été tirés dans les sens direct et inverse, et si cette vitesse de 7.100 mètres/sec. dans les Alpes n'est pas imputable au pendage ?

A propos de la relation entre température de l'air et vitesse dans la glace, la différence montrée entre les courbes de M. Brockamp et celle de l'expédition française ne peut pas étonner : la glace est une roche sédimentaire composée de couches qui ne sont pas nécessairement caractérisées par une vitesse constante. Peut-être devra-t-on tracer une ligne moyenne ou même une courbe.

M. Robin, Membre de l'Expédition au Queen Maudland (Antarctic) 1948-1950, présente quelques résultats séismiques :

Des sondages séismiques par tirs de réflexion ont été entrepris sur un profil s'étendant de la côte vers le sud sur une distance de 600 km. L'auteur a montré une coupe le long de ce profil, indiquant les épaisseurs de glace mesurées et la forme du socle rocheux. (Pour plus de détails, consulter la publication : Depths of Polar Ice Caps par A. Robin et J. J. Holtzscherer, *Journal of Geography,* London, June 1954.)

Le *Dr Brockamp* intervient. Il rappelle les premières mesures séismiques entreprises par l'Expédition A. Wegener en 1930-1931 au Grœnland. Il exprime sa satisfaction de voir ces mesures développées à grande échelle par les Expéditions Polaires Françaises. Il suggère que, pour les Expéditions futures, des mesures soient effectuées à proximité des côtes; l'utilisation d'un séismographe mécanique doit pouvoir rendre de grands services, en particulier pour

l'étude des ondes de surface. On pourrait éliminer la déformation des ondes enregistrées par l'intermédiaire d'amplificateurs.

Le *Dr Wanner* demande ce qu'on peut savoir de l'érosion actuelle au Grœnland.

Le *Prof Rothé* fait ressortir le contraste entre la pénéplaine centrale grœnlandaise et le profil mouvementé qui a, au contraire, été mis en évidence dans l'Antarctique par M. Robin.

Mr. *Lewis*, Géographe-Glaciologue, donne quelques renseignements sur les phénomènes d'érosion liés à des questions de température au contact roche-glace. Si le sol est gelé constamment, l'érosion n'existe probablement pratiquement plus.

Le *Prof. Rothé* pense que cette érosion a dû être très active au moment où l'Inlandsis s'est installé.

A 14 h. 45 m., les Membres se réunissent à nouveau dans la salle des séances de l'Association.

Suite du programme

16.— Communications scientifiques : Ondes séismiques (suite).

16. — *J.G. Scholte :* A mathematical discussion of seismic waves diffracted by the Earth's core.

17. — *M. Ewing, Fr. Press, J. Oliver, D.H. Shurbet* and *W.L. Donn :* Transformation, Absorption and Scattering of short-period Surface Waves at Continental Margins.

18. — *J. Oliver, Fr.Press* and *M. Ewing :* Model Seismology Study of refracted and diffracted Waves.

19. — *N. Jobert :* Influence de la Sphéricité de la Terre sur le début des Ondes de Love.

20. — *J. Mokrovic :* Les hodochrones pour tremblements de terre à foyers normaux déduites des observations de Zagreb.

16. Communications scientifiques : Ondes séismiques (suite)

16. — Le *Dr J.G. Scholte* présente sa communication : A mathematical discussion of Seismic Waves diffracted by the Earth's core.

In order to permit a detailed discussion of waves beyond $\triangle > 105^{o}$ it is necessary to calculate the amplitude of waves which have been diffracted by the Earth's core. This calculation, which is presented here has been carried out in three steps.

In the first place the most simple kind of wave-system possible in an infinite, elastic medium surrounding a liquid sphere, has been investigated; such a system consists of spherical waves which are concentric with the sphere O. By means of the boundary conditions the ratio between the amplitude of the incident wave and the amplitudes of the reflected and refracted waves has been calculated (§ 2).

However in actual conditions the incident wave emerges from a point A outside the sphere O (the core), so this wave is a spherical wave with its centre at A and not at O. This « A wave » is equivalent to an infinite series of « O waves »; as the reflected wave caused by each of these partial « O waves » is known (calculated in § 2), it is

easy to obtain the whole reflected wave in the form of an infinite series. By means of the Watson-transformation this series can be changed into an integral (§ 3).

The third step consists in approximating this integral; for points situated in the « lit » area ($\triangle < 105^{\circ}$) a first order saddle-point approximation yields the well-known results obtained by Zoeppritz (§ 4). In points of the shadow area this approximation is not usable; the amplitudes of these waves have been obtained by developing the integral into a series of residues (§ 5).

It appears that the amplitudes of the diffracted waves decrease exponentially; a penetration of 10 degrees epicentral distance into the shadow area causes a diminution of 50 % for waves with a period of about 10 seconds.

Le sujet de la communication du Dr J. G. Scholte fait partie d'une étude qui sera publiée ultérieurement par l'Institut Météorologique de De Bilt.

Prof. Jeffreys : This paper is of great interest. Miss Lehmann's observations gave similar results. For PKP a very sharp drop was observed. For diffraction : a very first approximation shows that the drop should not be fast.

Dr. Pekeris : This is excellent for radio cases but here it is a transient phenomenon.

Prof. Gutenberg : The problem is whether these waves are diffracted or refracted, the travel times are not sufficiently accurate to decide.

Rev. Dr. Ingram : Has the formula for amplitudes of Scholte solved the question ?

Dr. Scholte : No, because there are still too many unknowns about boundary conditions at the core.

Miss Lehmann : The amplitudes vary from station to station.

17. — *Professor Ewing* reads the paper : Transformation, Absorption and Scattering of short period Surface Waves at Continental Margins by Messrs. *M. Ewing, Fr. Press. J. Oliver, D. H. Shurbet* and *W. L. Donn.*

Many lines of investigation suggest that the continental margin is a very effective barrier for short period surface waves ($T < 15$ sect. $\pm$). It is postulated that

(a) short period surface waves of Love or Rayleigh type are effective scattered and transformed into the opposite type at continental borders and islands;

(b) short period Rayleigh waves are entirely absent over typical oceanic paths. This is probably an effect of de-coupling introduced by the velocity gradient in the water. All short period surface waves over these paths are Love waves.

(c) The great duration and unexpected components of motion in Lg, Rg and short period ocean surface waves are due to scattering and transformation.

(d) Storm microseisms are effectively generated only when an atmospheric energy source covers an area of rapid gradient in crustal thickness.

Le texte complet de la communication ci-dessus doit paraître

ultérieurement dans « *Bulletin of the Seismological Society of America* ».

Dr. Bath : The study of microseisms generated in the Atlantic is in complete agreement with these results : the barrier is also effective.

Prof. Ewing : The storms observed at Palisades come from the N. W.

Dr. Benioff : What mechanism can we suggest to act as a barrier ?

Prof. Ewing : The waves travel in a plate at the edge of the continent, the thickness of the plate changes.

Dr. Stoneley : The reflection at the continental edge is very interesting, how about refraction ?

Prof. Ewing : We have not observed them.

Dr. Press : The other surface waves will interfere.

Dr. Pekeris : What is the expectancy of observing the 2nd branch of the dispersion curve ?

Prof. Ewing : In the analogous problem in the water the absence is not easily explained. The explanation may be due to the gradient in the water.

18. — *Dr. Fr. Press* presents the paper : Model Seismology Study of refracted and diffracted Waves by Messrs. *J. Oliver*, *Fr. Press* and *M. Ewing*.

Knowledge of the propagation of elastic waves in the earth may be gained by studying elastic waves of ultrasonic frequencies traveling through small scale models. The models may serve as analog computers to reduce computational time and labor, or they can produce experimental solutions of problems at present theoretically intractable. As examples of the latter class, problems analogous to the propagation of diffracted P and refracted and diffracted PKP waves in and near the earth's core have been investigated. Simple models indicate the possible existence of previously unsuspected phases on earthquake seismograms, as well as clarifying observed travel time curves for diffracted waves.

This paper has been partially published in *Geophysics*, Vol. 19, pp. 202-219, 1954 (11 fig.) and *Ibid.*, pp. 388-401 (13 fig.).

Prof. Gutenberg : This paper marks the beginning of an era of comparison of experiment and observation.

Dr. Pekeris : What are the amplitudes in the shadow zone ?

Dr. F. Press : Amplitude work hasn't been done yet but will be done by comparing with surface wave amplitudes.

19. — *Madame N. Jobert* présente sa communication : Influence de la Sphéricité de la Terre sur le début des Ondes de Love.

En supposant un déplacement brusque en un point situé à l'intérieur d'une couche élastique sphérique recouvrant une sphère élastique homogène de propriétés différentes, on a obtenu le mouvement dû aux ondes de Love en un point de la surface, et on a fait la

comparaison avec le cas d'une couche plane recouvrant un milieu élastique indéfini, étudié par H. Jeffreys.

Par suite de la courbure, le début du train d'ondes est étiré vers l'avant; les premières oscillations, de longue période, arrivent avec une vitesse supérieure à la vitesse des ondes SH dans le milieu inférieur, et donnent lieu à un mouvement d'amplitude plus lentement croissante.

Le texte complet de la communication ci-dessus a été publié dans « Annales de Géophysique » (Paris) sous le titre : Effet de la Courbure de la Terre sur les Ondes de Love *(Annales de Géophysique,* tome 11, N° 1, 1955, pp. 1-48, 16 fig.).

Le *Prof. Dilgan* demande : S' est-on assuré de la convergence uniforme des intégrales ?

Mme Jobert : Non, et elles sont fort probablement divergentes. Je n'ai pas cherché la rigueur mathématique, mais la méthode simplifiée que j'ai utilisée doit pouvoir se justifier par le fait que le résultat trouvé peut être comparé au résultat pour le plan, calculé par une méthode plus rigoureuse par d'autres auteurs.

Dr. Scholte : Pourquoi ne pas avoir utilisé des transformées de Laplace au lieu d'intégrales de Fourier ? Ne serait-ce pas plus simple ?

Mme Jobert : Cela doit revenir à peu près au même.

Dr. F. Press : Quelle est l'augmentation de vitesse de phase ?

Mme Jobert : Environ 10%.

Dr. Benioff : Il semble qu'une phase d'ondes longues ayant le même début (une très grande demi-oscillation) a été enregistrée à Pasadena.

20. — Le *Dr. J. Mokrovic* présente sa communication intitulée : Les hodochrones pour tremblements de terre à foyers normaux déduites des observations de Zagreb.

Le Dr. J. Mokrovic a publié dans « *Abhandlungen des Geophysikalischen Instituts der Naturwissenschaftlich-mathematischen Fakultät der Universität in Zagreb,* III. Serie, Nr. 2 » (Zagreb, 1952) un article intitulé « Die Hodochronen von Zagreb für Erdbeben normaler Tiefen ». Comme ce mémoire est en langue croate, le Dr. Mokrovic présente devant l'Assemblée un résumé en langue allemande :

« In der genannten Arbeit habe ich, direkt und aus den Beobachtungen allein, Hodochronen aller in Zagreb hauptsächlich als Impetus registrierten Phasen hergeleitet.

Zu diesen Zwecken habe ich 181 Erdbeben von 1917 bis einschliesslich 1936 und von 17° bis 165° Epizentralentfernung von Zagreb aus regional begrenzten und tektonisch verschiedenen Gebieten der Erde bearbeitet. Infolge der Begrenzung der Distanz nach unten sind die europäischen Beben nicht berücksichtigt. Am stärksten sind der asiatische Teil des mediterranen Gürtels mit 45 Beben und der nordwestliche Rand des Pazifischen Ozeans mit 46 Beben vertreten. Dann kommen Indonesien mit 30, das südwestliche Gebiet des Pazifiks mit 25 und Mittel-Amerika mit 12 Beben. Das pazifische Ufer von Süd-Amerika und der Atlantische Ozean geben je 8, Alaska

und Karibisches Meer je 3 Beben. Afrika ist nur mit einem Beben vertreten.

Die Epizentren und ihre Entfernungen von Zagreb sowie die Epizentralzeiten der Erdbeben habe ich dem I.S.S. entnommen, zur Ausgleichung der beobachteten Laufzeiten einzelner Phasen eine teils rechnerische, teils graphische Mittelungsmethode angewandt.

Die so gewonnene neue Zagreber Pn-Hodochrone wurde mit einigen älteren Hodochronen derselben Phase verglichen. Es ist bemerkenswert, dass sie durchwegs zwischen den statistischen Hodochronen von Jeffreys und Bullen aus 1935 und 1940 liegt, von denen die zweite um ungefähr 6 Sekunden über die erste parallel verschoben ist.

Wie bekannt, glaubte A. Mohorovicic, man könnte seine statistisch berechneten Multiplizitäten mit durchschnittlichen Zeitabständen von 8 Sekunden auf Diskontinuitätsflächen unter der Erdkruste zurückführen, und aus dem Beginn einzelner Multiplizitäten deren Tiefen berechnen.

Ausserdem hat A. Mohorovicic im Jahre 1914 konstatiert, dass einzelne Beben an gewissen Stationsgruppen auch verspäten und zwar um eine Zahl von Sekunden, welche den Multiplen der Zahl 8 nahe sind. Diese *zu späten* Bebenbeginne hat er teils der Bebenschwäche, teils der kleineren Empfindlichkeit der Instrumente an den betreffenden Stationen zugeschrieben.

Bei der Häufigkeitsuntersuchung der Abweichungen der Einsatzzeiten longitudinaler Pn-Wellen in Zagreb von der neuen Pn-Hodochrone habe ich am häufigsten Abweichungen von —3 und +6 Sekunden gefunden. Hinsichtlich ihrer Verteilung nach Distanzen sah ich es aber nicht als gerechtfertigt an, im Sinne von A. Mohorovicic, noch zwei parallele Multiplizitätshodochronen zu ziehen.

Im Gegensatz zu Mohorovicic's statistischen Resultaten haben indessen B. Gutenberg und C. F. Richter in Anfangsteilen der Registrationen des Seismographen Benioff in Pasadena für einige Beben aus verschiedenen Erdteilen in einem gewissen Distanzintervalle 11 *reelle* Multiplizitäten vermutet. Diese Multiplizitäten führten sie aber weder zu einer Beziehung zu dem Vorgang im Epizentrum, noch zu der Station oder dem Wellenwege.

Am Anfang der Zagreber Seismogramme habe ich jedoch mit Sicherheit zwei reelle Phasen konstatiert.

Die erste Phase P_α mit einer etwas verstärkten Amplitude tritt nur im Distanzintervalle von 23° bis 87° und in einem durchschnittlich konstanten Zeitabstande von 14 Sekunden auf, die zweite $P\beta$ Phase mit noch stärkerer Amplitude nur von 41° bis 85° in ebenfalls durchschnittlich konstantem Abstande von 26 Sekunden nach der Pn-Phase. Ihre Hodrochronen laufen also in den genannten Distanzintervallen sowohl zueinander als auch zu der Pn-Hodochrone durchwegs parallel.

Es ist in erster Linie bemerkenswert, dass der Zeitabstand dieser Hodochronen von der Pn-Hodochrone nicht von der Epizentralentfernung abhängt.

Aus den Angaben einzelner Stationen hat auch A. Mohorovicic gefunden, dass zwischen Emersio und Impetus am Anfang einer normalen Pn-Welle ein durchschnittlich konstanter Unterschied von 8 Sekunden besteht. Diesen Unterschied hat Mohorovicic mit Reserve

so erklärt, dass diese Wellen bei der Brechung an der unteren Grenze der Erdkruste in eine longitudinale und eine transversale Welle zerfallen, von welchen die zweite bis zur Erdoberfläche nach der ersteren eben um 8 Sekunden verspätet.

H. Jeffreys hat weiter in *zwei* solchen nachträglichen Impeten in Zeitabständen von 8 und 16 Sekunden bei Montana-Erdbeben interne Reflexionen zwischen oberen Erdschichten vermutet. Bei der Untersuchung der Erdbeben aus kleineren Distanzen als 25° hat er aber für *zwei* einfache Durchgänge durch die oberen Schichten Zeitabstände von 7 und 14 Sekunden gefunden, also um die Hälfte kleiner als die Differenzen von P_α und $P\beta$ gegen Pn.

In Gegenden, auf die sich seine Untersuchungen beziehen, hat H. Jeffreys eine Krustendicke von 18 + 15 = 33 km gefunden, während nach A. Mohorovicic in einer weiten Umgebung von Zagreb die Kruste eine fast doppelt so grosse Dicke hat.

Demnach könnte man auch die Phasen P_α und $P\beta$ analog als einen zweimaligen Durchgang der P-Welle durch die oberen Krustenschichten ansehen und zwar infolge ihrer Reflexion unter kleinem Winkel in nicht zu weiten Entfernungen von Zagreb.

Die anderen Resultate sind wohl aus der Zusammenfassung der Arbeit ersichtlich. »

Le texte complet de la communication du Dr. J. Mokrovic « Die Hodochronen von Zagreb für Erdbeben normaler Tiefen » a paru en langue croate : Josip Mokrovic, Zagrebacke hodochrone prostornih seizmickih valova za potrese normalnih dubina — *University of Zagreb, Faculty of Sciences, Geophysical Institute, Papers* (Radiovi), III. Ser. N° 2, pp. 1-50, Zagreb 1952.

La séance est levée à 18 heures.

SEPTIÈME SÉANCE

SAMEDI, 18 SEPTEMBRE (matin)

Programme

16. — Communications scientifiques : Ondes séismiques (suite)

21. — *M. Ewing, Fr. Press and J. Oliver :* Recent Studies on Lg Propagation.

22. — *M. Bath :* The elastic Waves Lg and Rg along Euro-asiatic paths.

23. — *M. Bath :* T phases on the borders of the Arctic Ocean.

24. — *D. H. Shurbet :* Bermuda T phases with large Continental paths.

25. — *M. Ewing* and *Fr. Press :* Mantle Rayleigh Waves.

26. — *H. Benioff :* Very Long Period Waves recorded with an electromagnetic Strain Seismograph and three minute period Galvanometer.

27. — *P. Caloi, D. Di Pilippo* e *M. C. Spadea :* Onde sismiche guidate dagli strati sedimentari (Terremoto della Val Padana del 15 Maggio 1951).

28. — *Sidney F. Danes :* On a Possibility of Shear Waves in the Earth's Core.

La séance est ouverte à 9 h. 15.

16. Communications scientifiques : Ondes séismiques (suite)

21. — Le *Professeur Ewing* présente la communication : Recent Studies on Lg Propagation by *M. Ewing, Fr. Press* and *J. Oliver.*

Lg is a short period large amplitude surface wave which propagates with the velocity of shear waves in the silicic crust. Although wave guide transmission is required to explain the large amplitude, the nature of the wave guide is as yet unknown. A discussion of possible modes of propagation of Lg is given. Recent observations of Lg in North America, Europe, Asia and Africa are described.

A part of this paper is in press in the « *Bulletin of the Geological Society of America* » under the title « Crustal Structure of the Arctic Regions from the Lg Phase » by Oliver, Ewing and Press. The second part will be prepared and submitted to the « *Bulletin of the Seismological Society* » by Ewing, Press and Oliver.

Sir Harold Jeffreys said that the entry of a phase is often recognized by the appearance of a short-period superposed on a longer one, though there is no great change of amplitude. In a near earthquake Lg would have been identified as Sg.

Two of the most difficult problems of seismology are the existence of the irregular movement that persists between the recognized phases, and the prolongation of the coda far beyond the time corresponding to the slowest group velocities predicted theoretically. The idea of reflexion and refraction may help us to understand the length of the coda.

In the dispersion of surface waves we should expect theoretically that from Sg the displacements should increase up to a maximum corresponding to a minimum group velocity, and then suddenly cease.

Something like this was noticeable in the Strasbourg and Zürich records of the Jersey Earthquake of 1926, but this is unusual. Irregular refraction may also help us to understand how the characteristic effect of minimum group velocity is smoothed out.

Dr. Pekeris : The cut-off shouldn't be so sharp, there should still be a few oscillations, but not so many.

Dr. De Bremaecker : Does the direction of approach as seen from 3 component seismographs vary ?

Prof. Ewing : The phase relation varies too rapidly for readings. For California shocks due West the North South components are very important.

Mr. Hughes : What is the maximum distance for Lg ?

Prof. Ewing : It is the maximum distance for continental paths.

22. — *Dr. M. Bath* reads his paper : The elastic Waves Lg and Rg along Euroasiatic paths.

An investigation of Lg and Rg waves along Euroasiatic paths has been made using nearly 400 earthquake records at Uppsala and some for Kiruna and Bergen. To the author's knowledge this is the first detailed investigation of these waves for Euroasia. The Lg wave is composed of at least two different waves : Lg1 with group velocity = 3.54 ± 0.07 km/sec. and Lg2 with group velocity = 3.37 ± 0.04 km/sec. These two waves are statistically very well separated from each other, a result obtained from the frequency distribution of the velocities. In addition they both show sharp onsets in individual records. Lg2 has a larger energy than Lg1, and Lg2 has a maximum energy for focal depths slightly below normal. A model based upon the assumption of a low-velocity layer, has been proposed to explain the existence of two (or possibly three) distinct Lg waves. The wave motion of both Lg1 and Lg2 is mainly transverse horizontal; the wave motion of Rg (group velocity = 3.07 ± 0.10 km/sec) is retrograde elliptic in the plane of propagation. The periods of Rg waves are significantly correlated to group velocity, epicentral distance, and amplitude. Energy calculations show that the ratio of energy of Lg or Rg to the energy of body waves decreases with increasing magnitude. Locations of epicentres of earthquakes with exceptionally good Lg and those with no Lg or Rg show certain striking regularities. Large parts of the bottom of the Arctic Ocean have a continental structure.

Le texte complet de cette communication a paru dans « *Arkiv för Geofysik*, Band 2, N° 13, pp. 295-342, 7 figs., Uppsala 1954.

Prof. Gutenberg : In the Kern Co. shocks many stations were available : the travel-time curve starts several seconds later. Small shocks show large Lg because they seem shallower. A low velocity layer is preferred because of results of previous work and laboratory data.

Dr. Benioff : Are Lg2 and Lg3 observed when Lg1 is absent ?

Dr. Bath : Yes.

Prof. Gutenberg : Microseisms give the same results.

Dean S. Carder : Mountains are a slight barrier.

Dr. Wadati : What is the greatest depth for which this phase was observed ?

Dr. Bath : 580 km is exceptional, 230 km is a frequent occurrence.

Dr. F. Press : There is often an abrupt change between long and short period and it may be that Lg2 is the sequence of Lg1.

23. — *Dr. M. Bath* presents a third paper : T phases on the borders of the Arctic Ocean.

Several cases of clear T phases from earthquakes in the Norwegian Sea recorded at Kiruna since 1951 are studied. To the author's knowledge these observations are the first of this kind in Europe

and also the first so far to the north — on the borders of the Arctic Ocean. It is verified that T propagates as a sound wave through the water. Different phases, constituting T, have been identified, travelling along the land path as Pg, Sg, and a third wave with a land velocity of 2.7 km/sec, probably an S wave in more superficial layers than granite. The conditions for sound-channel transmission in the ocean are studied. The efficient use which can be made of the T phase in epicentre locations is illustrated with a particular case. The period of T is remarkably constant and equal to 0.5 sec. By amplitude calculations it is shown among other things that different submarine earthquakes are not equally efficient in producing a T phase; reasons for this behaviour are discussed. A theoretical explanation is given for the fact that at the same time as the amplitude of T may be larger than that of P at Kiruna, there is no T, but a clear P recorded at Uppsala.

La communication du Dr. Bath « A Study of T Phases recorded at the Kiruna Seismograph Station » a paru dans « *Tellus* », Vol. 6, N° 1, pp. 63-72, 2 figs., Stockholm 1954.

Dr. F. Press : Is there anything peculiar for ice-covered oceans ?

Dr. Bath : There is no ice on the oceans there.

24. — Le *Docteur Worzel* présente la communication de M. *D. H. Shurbet :* Bermuda T phases with large Continental Paths.

A short period arrival on records of the Bermuda-Columbia Seismograph Station is identified as the T phase. The path of propagation consists of land paths up to 51° preceding 14° of water path. It is shown that the travel time of this phase can be accounted for if the energy travels as the P phase over the land path and the T phase over the ocean path. Background noises in the Sofar channel do arise in some cases from earthquakes as much as several thousand miles inland.

The complete text of this paper will be published in *Bulletin of the Seismological Society of America.*

Aucune remarque n'est présentée.

25. — *Prof. Ewing* presents the paper : Mantle Rayleigh Waves by *M. Ewing* and *Fr. Press.*

Rayleigh waves with periods in the range 60-480 seconds have been recorded at Pasadena and Palisades, usually from earthquakes of magnitude 8 or larger. In the case of the Kamchatka earthquake of 4 November 1952, orders R6, R7... R15 were recorded at Palisades, the corresponding paths involving up to 7 complete passages around the earth. The dispersion data for periods below 400 seconds can be explained by the known increase of shear velocity with depth in the mantle, crustal layers having negligible effect. Levelling off of the group velocity curve for periods in the range 400-480 sec. suggests that these long waves are effected by the core.

A program for observing these oscillations at other stations as well as for extending the long period end of the spectrum is described.

Le texte complet de cette communication a paru sous le titre suivant: «Mantle Rayleigh Waves from the Kamchatka Earthquake of

November 4, 1952 » by Maurice Ewing and Frank Press, *Bull. Seism. Soc. Amer.*, Vol. 44, pp. 471-479, 1954, 3 Figs.

M. *De Bremaecker* demande si la différence systématique entre les trajets pairs et impairs est due au mécanisme au foyer.

Le *Prof. Ewing* répond affirmativement.

Mme Labrouste signale qu'elle a obtenu un bel enregistrement sur le séismographe à longue période du Parc Saint-Maur pour le séisme du 22 novembre 1952.

Le *Dr. Benioff* demande quelle est la période de l'appareil utilisé : Mme Labrouste répond que l'appareil a une courbe d'amplification très plate jusqu'à une période de 8 minutes.

26. — *Prof. H. Benioff* reads his paper : Very long period Waves recorded with an electromagnetic Strain Seismograph and three minute period Galvanometer.

An electromagnetic linear strain seismograph having a galvanometer of three minutes period has been in operation at the Seismological Laboratory in Pasadena for several years. Owing to its unusual period-response characteristics, seismograms of great earthquakes written with this instrument differ considerably from those written with conventional instruments. Body waves and surface waves with periods less than 20 seconds or so, which ordinarily dominate seismograms of conventional instruments, are relatively inconspicuous, whereas simple impulses or wavelets with periods ranging from 1 to 60 minutes show the largest amplitudes. In the seismogram of the Kamchatka earthquakes of November 4, 1952 the recorded long period wavelets include mantle Rayleigh waves, mantle Love or G-waves, and a wave group having periods of 2.8 and 2.18 minutes with a travel time corresponding to a Rayleigh wave excited at the antipodal point of Kamchatka.

Successive G-wave impulses exhibited very little dispersion and were readable up to G6. Their transmission time around the earth remained constant at 152.2 minutes corresponding to an angular speed of 2.365 degrees per minute and a linear speed of 4.384 km/sec. The first Rayleigh wave was also a simple impulse but owing to dispersion the later Rayleigh arrivals formed wave trains. The longest periods observed in waves identified as of Rayleigh type was 7.8 minutes. An unidentified wave or oscillation having a period of 57 minutes was clearly recorded. This oscillation may possibly represent a free vibration of the earth as a whole either in a mode in which its form oscillates alternately between a prolate and oblate spheroid or else in a mode in which two hemispheres rotate in opposite directions about a common diameter.

Another long period pulse lasting more than 12 hours was observable on the seismogram. It is suggested that this pulse may represent a heavily damped readjustment of the crustal or mantle strain over the whole earth in response to the local strain-release which generated the earthquake.

Le texte complet de la communication ci-dessus doit paraître ultérieurement dans « *Bulletin of the Seismological Society of America* ».

Prof. Jeffreys : What is the period of the rod itself ?

Prof. Benioff : 1/50 sec.

Dr. Bath : What is the estimate of the free period ?

Dr. Tsuboi asked if there is any indication that those earthquakes which are accompanied by the long waves are of larger magnitudes and those which are not accompanied by them are of smaller magnitudes.

Dr. Benioff answered no.

Then *Dr. Tsuboi* said that from the view point of the deformations of the earth's crust, earthquakes may be divided into two categories, A and B.

In A, the deformations at the time of the earthquake and after it are similar in shape (for example : The Tango Earthquake of 1927), while in B, they are opposite (for example : The Kwanto-Earthquake of 1923).

27. — Le *Prof. D. Filippo* présente la communication : Onde sismiche guidate dagli strati sedimentari (Terremoto della Val Padana del 15 Maggio 1951) par *P. Caloi,* D. *Di Filippo* et *M. C. Spadea.*

Les stations séismologiques placées sur des couches d'alluvions plus ou moins épaisses et consolidées, enregistrent, spécialement à l'occasion de tremblements de terre voisins, toute une série d'oscillations, dues à des phénomènes de réflexion, réfraction et diffraction, déterminés par le passage de l'énergie séismique à travers les surfaces ou les zones qui séparent les unes des autres les couches sédimentaires.

Le tremblement de terre de la Vallée du Po du 15 mai 1951 a fourni des exemples d'exceptionnel intérêt à cet égard. A ce tremblement a été consacré un long mémoire qui sera bientôt publié. Ici nous désirons attirer l'attention sur le grand nombre d'oscillations guidées par les couches sédimentaires et inscrites dans les stations séismologiques de la Vallée du Po.

La majeure partie de ces oscillations s'éteignent au bord de la Vallée du Po : seules persistent et viennent s'enregistrer dans les stations séismologiques européennes certaines ondes, longitudinales et transversales, désignées par les symboles Ps et Ss, se propageant avec des vitesses moyennes de l'ordre de 4 km/sec. et 2,5 km/sec. respectivement.

Ces ondes sont caractéristiques des couches constituant sur tout le continent européen une couverture généralement diffuse avec une épaisseur variable.

Le texte complet de la communication ci-dessus est publié en langue italienne dans « *Annali di Geofisica* », Vol. VIII, N° 1, 1955, pp. 9-21, 6 fig.

M. *Peterschmitt* demande où se place l'épicentre microséismique sur la carte macroséismique. Le Prof. Di Filippo répond : dans la partie sud de l'ellipse d'intensité maximum.

Le *Professeur Rothé* demande si l'on a des données sur l'épaisseur des couches sédimentaires dans la Vallée du Po et si l'on a pu atteindre le socle par forage.

Le *Prof Di Filippo* répond que la prospection séismique indique que le sédimentaire a une épaisseur moyenne de 5 à 6 km. Son maximum d'épaisseur se trouve au voisinage de l'épicentre; là aussi se trouvent des exploitations de méthane. L'épaisseur va en diminuant vers Trieste et Salo.

Le *Prof. Caloi* indique qu'on dispose de données de forages jusqu'à 3 km de profondeur, mais que les données de ces forages sont variables.

28. — La communication de *M. Sidney F. Danes :* « On a Possibility of Shear Waves in the Earth's core » est déposée sur le bureau.

Partition of energy of seismic waves reflected from, and penetrating through, an incompressible solid core is computed from Zoeppritz's matrices. Results are plotted against angle of incidence and epicentral distance. Waves K are interpreted as a continuation of waves S, whereas longitudinal waves are totally reflected. The application to the actual earth's core is open for discussion.

La séance est levée à 11 h. 45.

HUITIÈME SÉANCE

LUNDI, 20 SEPTEMBRE (matin)

Séance commune avec l'Association de Volcanologie

Programme

17. — Distribution du Rapport sur l'Age de la Terre et présentation d'un fichier bibliographique (J. T. Wilson).

16. — Communications scientifiques : Radioactivité.

29. — *H. S. Brown and C. C. Patterson :* Report on the Determination of the Ages of Rocks and Minerals, on the Age of the Earth and the Isotopic Evolution of Lead.

30. — *D. W. Allan :* L'âge de la Terre calculé d'après la Méthode du Plomb.

31. — *R. M. Farquhar :* Variations de la composition du Plomb ordinaire en isotopes.

32. — *H. Faul :* On the Motion of Radon-Bearing Natural Fluids.

33. — *L. T. Aldrich, G. R. Tilton, G. L. Davis, L. O. Nicolayson and C. C. Patterson :* Comparison of U-Pb, Pb-Pb and Rb-Sr Ages of pre-Cambrian Minerals.

34. — *M. Ferretti, C. Festa e F. Ippolito :* On the Radioactivity of the Vesuvius Lavas.

35. — *J.-P. Rothé :* La Radioactivité des Vosges hercyniennes.

La séance est ouverte sous la présidence du Dr Marble.

17. — *Le Prof J. T. Wilson* présente le Rapport qu'il a rédigé avec *Sir Edward Bullard.* Ce rapport est intitulé : Report on Radioactivity, age of minerals and heat flow.

As J. T. Wilson, R. D. Russell and R. M. Farquhar were writing a chapter on Radioactivity and age of minerals for a new edition of « *Handbuch der Physik* » at this time, this report is largely based upon their work, with the kind permission of the editor Dr. J. Bartels. Consequently this report not only deals with work carried out during the past three years, but gives a summary of the present state of these investigations.

Le *Prof. Wilson* présente également un fichier bibliographique qu'il a établi concernant les questions de radioactivité.

16. Communications scientifiques : Radioactivité

29. — Le *Prof. Harrison Brown* présente la communication intitulée : Report on the Determination of the Ages of Rocks and Minerals,, on the Age of the Earth and the Isotopic Evolution of Lead by *H. S. Brown* and *C. C. Patterson.*

Following the development of the « isotope dilution » technique for the determination of geologic time (1) a special laboratory has been designed and constructed at the California Institute of Technology for the purpose of applying the new techniques to a wide variety of substances. The primary feature of the new laboratory is the low level of lead contamination in the air, the reagents and the equipment. This feature enables one to isolate lead from rocks and minerals without contaminating it with « ordinary lead » impurity. The laboratory made possible the isolation, without excessive contamination, of lead from an iron meteorite although the element was present at a concentration of only 0,3 parts-per-million (2). The laboratory and procedures are described.

Other features of the geochronology laboratory include facilities for crushing and pulverizing rocks, separating minerals under conditions of low lead-contamination, autoradiography, petrography, radioactive counting, mass spectroscopy and rock analysis.

With the facilities available lead has been isolated from the Canyon Diablo meteorite (2) and more recently (by Patterson) from the Henbury meteorite. The isotopic compositions of these leads are nearly identical and there is good reason to believe that they represent the

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(1) George R. Tilton, Claire C. Patterson, Harrison Brown, Mark Inghram, Richard Hayden, David Hess and Esper Larsen, Jr., *Report AECU - 2840, United States Atomic Energy Commission, Technical Information Service, Oak Ridge, Tenn., U.S.A.*

Also.: *Bulletin of the Geological Society of America (in press).*

(2) C. Patterson, H. Brown, G. Tilton and M. Inghram, *Phys. Rev.* Vol. 92, 1234-1235 (1953).

isotopic composition of lead at the time the earth was formed. One of us (Patterson) more recently has been working on the problem of isolating lead from stone meteorites.

In collaboration with other workers, the facilities available are now being applied to studies of the distribution of the radioactive elements and the isotopes of lead in igneous rocks and sediments. The bearing of the results obtained thus far on the age of the earth and the determination of geologic time are discussed.

A large part of this work has been sponsored by the United States Atomic Energy Commission.

Prof. Houtermans remarks : The 207/206 age given by Dr. Brown is independent of the figures on U content. It may well be that some chondrites have been formed at a more recent time, say 100 million years and that the present high content of U found by Dr. Brown has been added at this time; the 207/206 ratio then would not have been affected appreciably.

Prof. Harold C. Urey : I congratulate Professors Brown and Patterson on their most interesting paper. However it surprises me very much that the uranium content of chondritic meteorites should be so variable, i. e., Modoc 10-^{8}; Forest City, $19 \times 10\text{-}^{8}$ and Laredos, $14 \times 10\text{-}^{8}$ all in g/g. The chondritic meteorites are remarkably constant in composition when judged from the best analyses. Some recent measurements by Dr. B. Elvey and myself show that the variation of Na, K, and Rb are very small in chondritic meteorites. i. e. some 10 or 15 %. One can only wonder as to the chemical processes that can change the U and Th abundances without changing the abundances of some other elements such as K which is concentrated with U and Th so markedly in the crust of the Earth.
The higher abundances of U and Th reported by these authors if characteristic of the Earth's mantle would result in quite an embarrassing generation of heat in the earth.

Prof. Urey also remarked that recent measurements by Wasserburg at the University of Chicago confirm the meteorite age of 4.5×10^{-9} years. These determinations, by the $Argon^{40}/Potassium^{40}$ method are based, however, on a new and unconfirmed figure for the branching ratio of Potassium.

30. — Le *Dr Farquhar* présente la communication du *Dr Allan* intitulée : L'Age de la Terre calculé d'après la Méthode du Plomb.

Plusieurs chercheurs, dont le premier en date a été M. Arthur Holmes, ont calculé ce qu'on appelle « l'âge de l'écorce terrestre ». Les méthodes employées à cette fin se fondent sur l'hypothèse que les légères variations des rapports quantitatifs des isotopes de minerais de plomb contemporains Pb^{206}, Pb^{207} et Pb^{208}, à l'isotope Pb^{204}, proviennent entièrement des variations des rapports quantitatifs des isotopes de l'uranium et du thorium dont la transmutation produit les susdits isotopes du plomb, variations qui eurent lieu à l'époque de la formation de l'écorce terrestre.

Pour traiter de la justesse de cette hypothèse (1), l'auteur établit, par des calculs, que l'époque varie à peu près en fonction de la quantité et il démontre que toutes deux, conjointement avec les courbes moyennes d'époque et de quantité découvertes par plusieurs chercheurs, constituent une forte raison de croire que le gros de la variation des quantités de l'uranium et du thorium eut lieu dans un passé très reculé, et (2) il contrôle les quantités mesurées de plus de 70 minerais de plomb à peu près contemporains. Le tracé graphique de ces quantités doit aboutir à des lignes droites, si les hypothèses susmentionnées sont justes, et donner des diagrammes qui soient assez rectilignes pour justifier le calcul de « l'âge de l'écorce terrestre » d'après ces résultats. Certaines raisons données portent à croire que ces résultats représentent réellement, non l'époque de la solidification de l'écorce, mais celle de la solidification du manteau terrestre.

Le résultat numérique obtenu varie de 3.6×10^9 années à 4.6×10^9 années, selon le groupe de minerais ayant servi aux calculs et le mode de calcul. L'auteur estime que le résultat le plus exact est d'environ 4.4×10^9 années, nombre qui concorde bien avec un résultat obtenu par M. Houtermans en combinant des connaissances tirées de minerais de plomb et de météorites, ces dernières provenant du travail de M. Patterson, et avec des calculs extraits directement de connaissances obtenues par ce dernier relativement aux météorites.

A longer article on this subject entitled « The Age of the Earth from Lead Isotope Abundances by R. D. Russel and D. W. Allan has been submitted to the Royal Astronomical Society for publication in « *Monthly Notices (Geophysical Supplement)* ».

Dr Marble said that the problem to-day is certainly more complex than it was 25 years ago.

Prof. Bullard agreed that the history of the lead ores is undoubtedly complex. It is likely that there have been several cycles of separation of lead from uranium.

Prof. Houtermans : It seems to me very satisfactory that the figures obtained by D. W. Allan for the age of the earth's crust which have been presented, seem to have a tendence to increase if isotopic abundances of lead from a wider area are used. The figures of Geiss for instance nearly all refer to lead ores from a Central-European area. There seems a tendency that the age calculated using Pb figures from world wide material converge toward $4{,}4\text{-}4{,}5 \times 10^9$y if isotopic abundances of Pb from a world wide survey are used for the calculations. We have to keep in mind that the two different ways of calculation for the age of common Pb used by Russell and coworkers assuming a uniform magma for all lead ores or otherwise the assumption of a differentiation into different kinds of magmas at the date of the formation of the earth's crust which corresponds to the original Holmes' model and the graphs used by our Berne group are both to be considered only as a first approximation of a far more complicated development of the isotopic abundances of Pb, involving gradual changes of the ratio U^{238}/Pb^{204} in the mother material of the Pb ore. I should not be surprised therefore if eventually extrapolations of the branching data of the isochronic fan would lead to different dates for different areas corresponding to different conti-

nental shields. However it seems that the calculations of Dr. Allan for the age of the earth's crust from purely terrestrial Pb figures justify the assumption made by Dr. Harrison Brown and his group and by myself to identify provisionally the isotopic abundances of primeval terrestric lead with those obtained from lead in iron meteorites.

Prof. Urey remarked that an age of common lead simply determines the separation of lead in uranium whenever it may have occurred.

Prof. Marble recalled that many of the leads give geologically reasonable ages, but a large group has been listed as « anomalous ». These leads may even give negative ages.

Dr. Faul said that it would seem that there are hardly any leads that are not « anomalous », if one uses the simple model.

31. — Le *Dr Farquhar* présente sa communication : Variations de la composition du Plomb ordinaire en isotopes.

L'auteur décrit les variations des quantités des éléments Pb^{206}, Pb^{207} et Pb^{208}, comparées à celles de l'élément Pb^{204}, qui se trouvent dans les minerais de plomb ordinaire. Il a tracé, à l'aide d'un grand nombre de résultats récents, des courbes moyennes indiquant comment les quantités varient en fonction de l'époque. On peut distinguer entre les minerais « normaux » et les minerais « anormaux », selon que les isotopes qui les constituent concordent ou non avec ces courbes. Ce qu'on connaît au sujet des minerais « normaux » corrobore les hypothèses de chercheurs précédents, qui supposaient que les variations en question proviennent de l'addition de plomb radiogène au plomb primitif, dans la matière originale qui a donné les minerais concentrés. Pour dater les époques de la séparation des minerais « normaux » d'avec la matière originale, on a pris la moyenne des courbes de l'époque en fonction de l'abondance.

L'auteur décrit aussi les variations notées dans certains gîtes de minerai, en matière des rapports quantitatifs supérieurs à la moyenne qui existent entre les éléments « anormaux » Pb^{206}, Pb^{207} et Pb^{208}, d'une part, et l'élément Pb^{204}, d'autre part. Il exprime l'avis que ces indices élevés s'expliquent simplement par l'addition d'assez grosses quantités de plomb radiogène. Bien que les indices des quantités d'isotopes contenues dans ces minerais « anormaux » ne permettent pas de fixer des dates parallèles aux courbes moyennes de l'époque en fonction de l'abondance, ils permettent peut-être de calculer l'époque supérieure à laquelle le minerai s'est séparé de la matière originale des additions de plomb radiogène.

L'auteur présente des conclusions générales concernant les applications des âges tirés de ces études, aux questions de déterminer la date des époques géologiques.

The material in the paper entitled « Variations in the Isotopic Constitution of Common Lead » is to be found in two separate papers: *1°* Dating Galenas by means of their Isotopic Constitutions by R. D. Russell, R. M. Farquhar, G. L. Cumming and J. Tuzo Wilson, in *Transactions of the American Geophysical Union,* Vol. 35, N° 2, pp. 301-309, 4 fig., publ. at Washington, D. C., April, 1954; *2°* Isotopic Analyses

of Anomalous Lead Ores by R.M. Farquhar and G.L. Cumming, *Transactions of the Royal Society of Canada*, Vol. 48, series III, section IV, pages 9-16, 1 fig., publ. by the Royal Society of Canada, Ottawa, June 1954.

Prof. Jeffreys pointed out that the determination of lead^{204} is subject to a considerable error, because of the low abundance of this isotope.

Dr. Farquhar agreed that this is a weak link in mass spectrometry.

Prof. Houtermans had compared results with the University of Toronto and the University of Bonn and found no difference within the standard deviations given. The figures can be trusted within these limits.

Dr. Marble : The use of the original data of Nier must consider (a) the small number of samples (b) the inclusion therein of « anomalous » leads from Joplin, Missouri and of poorly dated leads.

The use of the more recent data, which appear to be accurate and precise, and the obtaining of further data, will enable us to calculate the geological age of lead deposits and the « age of the crust » — or by whatever name this is called, with increased precision.

It must be remembered that there are considerable physical and chemical, as well as great geological and geophysical difficulties involved in this type of work.

Dr. Marble added that he still had remains of the samples originally investigated by Nier. If the individual workers would make their requirements known, these lead samples could be distributed for cross-checking purposes.

32. — Le *D*^{r} *H. Faul* présente sa communication : On the Motion of Radon-Bearing Natural Fluids (Sur la mobilité du radon dans les fluides naturels). *

L'émanation se dégage spontanément des substances radioactives réparties dans la nature. La quantité dégagée dépend de la concentration de la matière radioactive et du pouvoir émanateur de celle-ci. Le pouvoir émanateur varie du voisinage de zéro pour les zircons à presque 100 % pour les couches minces des sels de radium déposées dans les porosités de la roche.

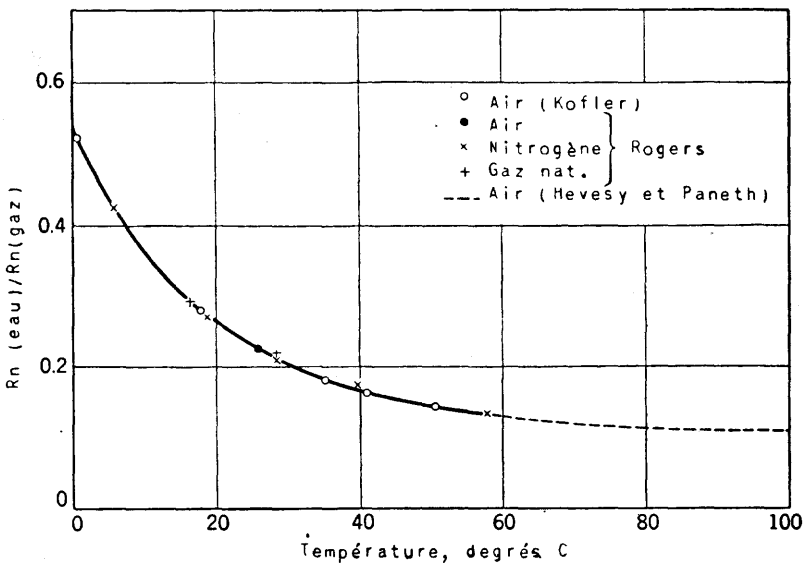
Le gaz ne forme pas de composés avec le milieu ambiant, et généralement la diffusion à travers ce milieu est faible par rapport à la vitesse d'écoulement du fluide avec lequel il se trouve mélangé. Ceci permet d'employer les équations de continuité pour l'émanation lorsqu'on connaît le mouvement du fluide. La théorie des mouvements des fluides a été faite principalement par Muskat (1). Ses résultats sont applicables pour l'émanation dans la plupart des cas rencontrés.

Les mesures d'émanation sont effectuées à l'aide d'une chambre d'ionisation et d'un électromètre « vibrating reed ». L'appareillage comprend cinq ou six chambres d'ionisation, ce qui permet de faire une vingtaine de mesures par jour, le tout étant monté dans une camionnette.

*) Publication authorized by the Director, U. S. Geological Survey.

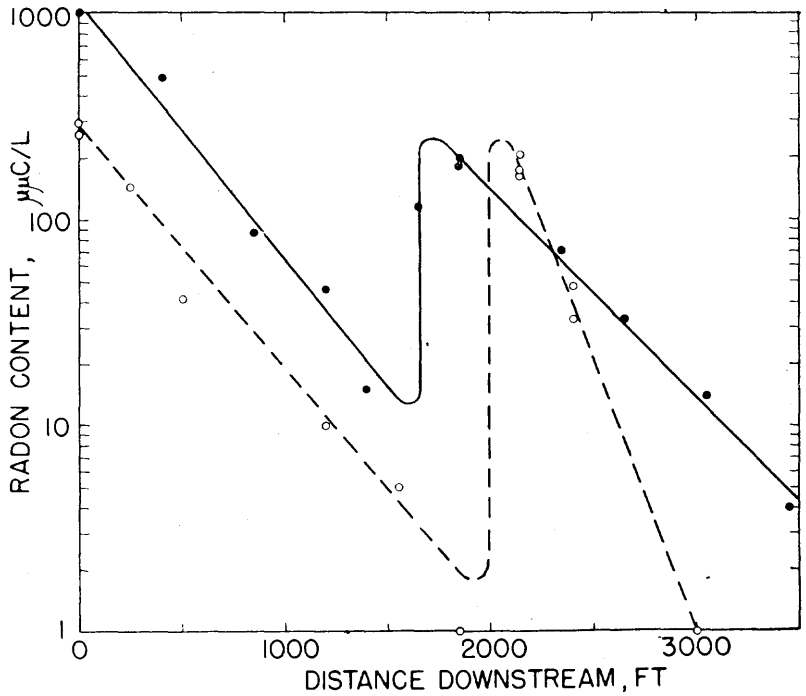
Les premières mesures furent effectuées dans le champ de gaz naturel d'Amarillo (Texas) afin de déceler l'origine de la teneur en émanation et en hélium de ce gaz. La seule détermination de la teneur en émanation ne renseigne pas sur la distance, d'ailleurs inconnue, entre la prise d'émanation et la substance radioactive ayant donné naissance à l'émanation. Mais si par un moyen quelconque (fermeture du forage) on arrive à obtenir l'équilibre dynamique du gaz et l'équilibre radioactif du radon, on peut ensuite ouvrir le tube du forage et on obtient pendant quelques dizaines d'heures un mouvement transitoire du gaz entraînant le radon. La mesure de la teneur en radon pendant ce régime transitoire permet de calculer la distance entre le forage et le lieu d'origine du radon (2). La théorie du régime transitoire a été faite par mon collaborateur, M. Sakakura (3), ainsi que l'application à la détermination de la distance parcourue par le radon dans le champ de gaz.

Après les études de transport de radon par le gaz naturel, Rogers a entrepris (4) l'étude du transport du radon par l'eau. Nous avons commencé par étudier la répartition du radon entre l'eau et l'air. Avec des instruments modernes nous avons vérifié les résultats obtenus par l'école de Vienne vers 1910. La courbe obtenue par eux, par Rutherford et par nous-mêmes est représentée, Fig. 1. Cette



courbe montre la variation du rapport radon contenu dans l'air au radon contenu dans l'eau en fonction de la température. La composition chimique du gaz n'entre pas en ligne de compte.

Ensuite Rogers a étudié la teneur en radon des rivières temporaires dans la contrée semi-aride de Utah située dans l'Ouest Américain. Ces rivières sont alimentées par l'eau provenant des couches aquifères dont il s'agissait de déterminer la position exacte. La Fig. 2 donne les courbes de teneur en radon de l'eau de deux rivières ali-



mentées par la même couche aquifère, en fonction du parcours de la rivière dans la région intéressée. L'emplacement des sommets correspond aux points exacts d'alimentation des rivières par la nappe souterraine en question. Les courbes en coordonnées semi-logarithmiques sont composées de portions de droites comme on devait s'y attendre. En effet, le rapport du radon contenu dans l'air au radon contenu dans l'eau reste presque constant, la température variant très lentement. La pente de la courbe dépend de la vitesse d'écoulement.

Une méthode similaire permet aussi, par exemple, de faire la mesure assez précise de la quantité d'eau perdue par infiltration autour et sous les barrages. Beaucoup de problèmes hydrodynamiques peuvent être résolus par des variantes de la méthode basée sur le dosage du radon dans l'eau.

Enfin, le transport du radon par l'eau a permis de localiser les gisements de la carnotite dans les couches de grès du Colorado où la structure géologique est assez simple. Dans les grès contenant les poches uranifères se trouvent incluses des lentilles d'argile. L'eau traversant les poches uranifères se charge de radon et continue à s'infiltrer jusqu'au moment où elle entre en contact avec l'argile. Elle suit alors la pente des couches. Les forages permettent alors de trouver en différents endroits la radioactivité gamma sur la surface supérieure de l'argile. L'étude statistique de ces anomalies permet de localiser le terrain où se trouvent les poches uranifères.

Ces quelques exemples donnent un aperçu de l'importance de la

mobilité du radon dans les fluides naturels et les conclusions pratiques que l'on peut tirer de la connaissance de cette mobilité.

Bibliographie

1) *Muskat, M.*, The Flow of Homogeneous Fluids through Porous Media, Mc Graw-Hill, New York, 1937.

2) *Faul, H.*, G. B. *Gott*, G. E. *Manger*, J. W. *Mytton* et A. Y. *Sakakura*, Radon and Helium in natural gas, Compt. Rend., 9e Congrès géologique International, Alger, Fasc. 9, 339-348, 1954.

3) *Sakakura, A. Y.*, The Equation of continuity in Geology (à paraître).

4) *Rogers, A.*, Thèse, Université de Utah, 1954.

Le *Dr Picciotto* demande : Votre travail permet-il de tirer des conclusions sur l'origine de l'hélium ?

Le *Dr Faul* répond : On ne peut pas dire si l'hélium s'est formé loin ou près. On sait que le radon se forme à proximité et que sa présence est favorisée par la porosité des roches. L'uranium est dans des résidus solides pétrolifères dans la roche.

Le *Dr Koczy* rappelle le travail de M. Lundberg sur cette question à appliquer à la recherche du pétrole par la prospection radioactive.

Le *Dr Faul* répond que la corrélation entre le pétrole en profondeur et les anomalies à la surface n'ont jamais été prouvées.

33. — Le *Dr H. W. Wells*, Carnegie Institution, Washington, présente la communication intitulée : Comparison of U-Pb, Pb-Pb and Rb-Sr Ages of Pre-Cambrian Minerals by *L. T. Aldrich, G. R. Tilton, G. L. Davis, L. O. Nicolaysen* and *C. C. Patterson.*

The ages of some minerals from pre-Cambrian granites have been determined by measuring the content of parents and daughters in three radioactive decay systems. The analyses were made by the method of isotope dilution. At most, 20 micrograms of element were required for mass-spectrometric analysis. Chemical procedures involved solvent extraction and ion-exchange separation as well as conventional methods. A summary of the calculated ages of minerals from five granites follows :

Granite Location	Mineral	Calculated Ages (million years)			
		U238/Pb206	U235/Pb207	Pb207/Pb206	Rb/Sr
Capetown S. Africa	Zircon	350	375	550±50	
	Biotite				820±40
Bagdad Arizona	Zircon	630	750	1120±70	
	Muscovite				1600
Uncompahgre Colorado	Apatite	1050	1380	1810±160	
	Biotite			1650	1650
Essonville Ontario	Zircon	1020	1050	1060	
Ohio City Colorado	Zircon	935	1110	1430±110	

The decay constants used are

$Rb^{87} \rightarrow Sr^{87} + \beta \qquad \lambda = 1.13 \times 10^{-11}\ yr^{-1},$

$U^{238} \rightarrow Pb^{206} + 8\alpha \qquad \lambda = 1.54 \times 10^{-10}\ yr^{-1},$

$U^{235} \rightarrow Pb^{207} + 7\alpha \qquad \lambda = 9.80 \times 10^{-9}\ yr^{-1}.$

and

In the Pb 207/Pb206 ages, the present day ratio, U238/U235, used is 138.0. The ratio, Rb87/Rb85, used is 0.386. The analytical errors of the derived ages do not exceed five percent unless otherwise indicated.

The disagreements in calculated ages between U/Pb and Pb/Pb cannot yet be explained. While the differences between the ages calculated by Rb/Sr and those from the uranium series were not expected, it is possible that they may be explained on the basis of the geochemistry of the elements involved.

The paper by Aldrich (L. T.), Tilton (G. R.), Davis (G. L.), Nicolaysen (L. O.) and Patterson (C. C.) is to be published in the « *Journal of the Geological Association of Canada.* »

Sir Edward Bullard : It is possible that the discrepancies between the ages determined from U/Pb and Rb/Sr ratios may not be due to experimental uncertainties or to the complexity of geological processes, but to a slow progressive change in the decay constants. Several authors have suggested that the constants of physics change by a large fraction of their present values in periods comparable to the « age of the Universe ». If such a change occurs it is likely that the periods of α and β decay processes would be affected differently. The rate of transformation of U to Pb is controled by the penetration of an α particle through the potential barrier of a U nucleus, whilst the decay of Rb to Sr is a much more sophisticated process involving the creation of a neutrino. The possibility of a difference can in principle be checked by determining whether the K/A ages agree with those from U/Pb or Rb/Sr.

A complication of this kind would be most unwelcome to those interested in the geological applications of radioactivity, but it would, of course, be of the greatest interest for physics and cosmology.

It is not suggested that a progressive change in decay constants is more than a possibility but it is believed that it is one that can not be altogether ignored.

Dr. Brown : I believe that we must learn a great deal more about decay constants and diffusion processes in rocks and minerals before we jump to such a conclusion. We have found, for example, that different minerals in a single rock can give different ages, largely because of migration of uranium, thorium and lead. I believe that we are dealing here with geologic processes rather than with changes in decay constants.

Prof. Houtermans recalled that the argon/potassium and lead/uranium ages obtained by Wasserburg agree.

Prof. Urey wanted to make it quite clear that Wasserburg's results are based on the assumption of 0.085 for the branching ratio of K^{40} whereas the previous figures were all around 1,1. The new figure is based on geological evidence and is not otherwise confirmed.

One of the Members said that as a geologist he was well aware that the history of a mineral is never simple. Original deposition may be followed by rearrangement and redeposition, which may produce

significant changes widely separated in time. For example : the geologic study of the Bikita area (dated by strontium/rubidium ages) reveals a long and complex history.

An other Member asked if it were not possible that there are radioactive chains which decay into lead^{204} ?

Prof. Harrison Brown said that this question has been investigated very thoroughly, but no such chains have been found.

Dr. Marble recalled that Prof. Trumann Kohman at Pittsburgh has been studying extinct radioactivities, i. e., the possibility of isotopic changes by the decay of radioactive elements with halflives of the order of the 10^8 years or less. No long-lived element that decays into lead^{204} has been found.

34. — Le *Dr. Festa* présente la communication intitulée : On the radioactivity of the Vesuvius Lavas by *M. Ferretti, C. Festa* and *F. Ippolito.*

We thought it of some interest to apply the method of the photographic plates to the study of the Vesuvius lavas. In particular we hoped to get the following information: a) whether the variation of the radioactive content of such lavas with the date of the eruption was confirmed; b) whether it was possible to localize the alfa-emitter centers (partial results on these two topics have been already published in a previous note); c) whether it was possible to find a method for deciding whether the Uranium family had already reached the radioactive equilibrium inside the sample, and, if not, to determine a superior limit for the time of rupture.

For the latter purpose, we tried to generalize the method of Buttlar and Houtermans for our case (The method was originally planned for the measure of the Uranium and Thorium content in homogeneous minerals, already in radioactive equilibrium). For the solution of this problem, we have seen that it is important to have statistical errors smaller than those generally admitted by other Authors, in order to get the values of the ratio Th/U with a reasonably good approximation. We decided therefore to count not less than 10^4 tracks for every sample. We have noticed then that the only way to fit the experimental results to the theoretical previsions was to take into account a number of facts, and it seems that the Radon diffusion through the surface layers of the sample has a considerable weight : this leads to superficial layers less active than expected.

A preliminary study made on a pitchblende sample gave a very good fit between the experimental and the theoretical curves, assuming for the alfa-diffusion coefficient through the mineral a value of 10^{-13} cm^2/sec.

It seems therefore impossible to get the results on the radioactive equilibrium inside a lava sample without determining beforehand by an independent method the diffusion coefficient of the Radon.

Le texte complet de la communication ci-dessus a paru en langue italienne dans « *Annali di Geofisica* » sous le titre : Sulla applicacione del metodo delle emulsioni nucleari allo studio della radioattività delle lave vesuviane, vol. VII, N° 4, pp. 539-546, Roma, 1954.

Le *Dr. Marble* voudrait savoir si les résultats obtenus sur les laves de l'Etna sont les mêmes que ceux concernant le Vésuve ?

Le *Dr. Picciotto* estime que les mesures sont encore trop peu nombreuses, car il faut tenir compte de la différence de nature des échantillons.

35. — Le *Professeur J.-P. Rothé* présente sa communication intitulée : La Radioactivité des Massifs granitiques des Vosges hercyniennes.

« J'ai déjà signalé, lors de l'Assemblée de Bruxelles, quelques résultats provisoires obtenus dans les Vosges en effectuant des mesures de la radioactivité des affleurements rocheux au moyen de gammamètres (1). En 1952 j'ai publié, avec mon collaborateur M. Peterschmitt, une note résumant les résultats fournis par des mesures sur des profils de reconnaissance comportant 205 stations réparties à travers les Vosges (2).

A la suite de ces premières mesures, le Commissariat à l'Energie atomique a bien voulu me charger d'établir la carte détaillée de la radioactivité des massifs cristallins des Vosges. Cette étude comporte, à raison d'une station de mesure par kilomètre carré, la mesure du rayonnement pénétrant émis par les roches. Les appareils employés sont, soit des gammamètres (type AVP à 9 compteurs G. M.), soit des gammaphones (C.E.R.E.), soit une chambre d'ionisation de Kolhörster déjà utilisée par E. Rothé dans les mesures initiales qu'il effectua dans les Vosges alsaciennes en 1934. Tous les appareils employés sont étalonnés par rapport aux valeurs en ions/cm^3/sec. fournies par les mesures à la chambre d'ionisation; cette chambre reste, en effet, un excellent appareil très fidèle, mais dont l'emploi sur le terrain est malheureusement peu aisé et nécessite de bons affleurements en dalles horizontales. On notera que 3 ions/cm^3/sec. équivalent à peu près à 2 microroentgens-heure. D'une manière générale, les mesures avec les différents appareils et ramenées en ions/cm^3/sec. en utilisant les formules d'étalonnages sont concordantes; en une même station, les écarts que présentent les valeurs individuelles sont souvent très faibles et dépassent rarement 5% de la valeur moyenne. Toutes les valeurs sont corrigées du rayonnement cosmique en fonction de l'altitude des stations.

Plus de 2.500 mesures ont été effectuées jusqu'ici et la carte complète comprendra environ 3.000 stations kilométriques.

L'interprétation détaillée des résultats est prématurée, le travail complet ne devant être achevé que dans quelques mois. Nous aurons alors à notre disposition, sous forme d'une carte radiogéologique en feuilles au 1:50.000e, une image précise de la répartition de la radioactivité dans un massif cristallin aussi complexe que le massif vosgien. Il ne peut être question ici de discuter en détail les résultats

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(1) Comité pour l'Etude de la Physique de l'Intérieur de la Terre, Comptes rendus des séances tenues à Bruxelles du 16 au 29 août 1951. *Annales de Géophysique*, Paris 1952, t. 8, p. 115.

(2) J.-P. Rothé et E. Peterschmitt, La radioactivité des Vosges hercyniennes, *C. R. Acad. Sciences*, Paris, t. 234, p. 1610-1612, 16 avril 1952 et une carte annexe.

qui sont liés à la connaissance précise de la géologie des Vosges. Je voudrais seulement indiquer quelques faits significatifs.

Les différentes zones granitiques se distinguent nettement les unes des autres par leur radioactivité. Certains granits (le granit du Champ du Feu et son faciès amphibolique, le granit du Hohwald) sont très peu actifs (8 à 10 ions) et le sont moins même que les schistes primaires encaissants (11 ions). Au contraire, la radioactivité dépasse 30 ions dans une bande de plus de 6 kilomètres de longueur en bordure sud du massif granitique du Ballon d'Alsace, le granit du Ballon prenant alors un aspect microgrenu. La radioactivité est voisine de 50 ions en plusieurs stations.

Nous donnerons ici un tableau qui permet de comparer plusieurs types de massifs granitiques. Les chiffres sont indiqués en %; toutes les valeurs ont été ramenées à la densité de 1 station par km².

	I < 10	10-15	15-20	20-25	25-30	> 30
Granit type Champ - du - Feu (142 stations)	47	53	0	0	0	0
Granits « intrusifs » du massif du Champ-du-Feu	0	24	47	29	0	0
Granit du Ballon d'Alsace	4	3	25	35	17	16

De nombreux autres massifs granitiques vosgiens ont ainsi été étudiés.

Je voudrais également mentionner sommairement ici les intéressants résultats fournis par les mesures effectuées sur les coulées acides et basiques qui, du dévonien au viséen supérieur, se sont accumulées sur de grandes épaisseurs dans le sud des Vosges. L'activité de certaines coulées (trachytes de Bourbach, orthophyre à sanidine de Rougemont) dépasse 30 ions. L'augmentation de la radioactivité des roches viséennes est particulièrement nette. Les coulées deviennent plus actives que celles de même type pétrographique, mais d'âge plus ancien. Les grauwackes viséennes qui contiennent des débris de ces coulées sont de 50% plus actives que les grauwackes tournaisiennes. L'accroissement de cette activité correspond à la phase de paroxysme de l'orogénie hercynienne.

Enfin comme exemple de carte radiogéologique, je présente la feuille du Massif du Champ-du-Feu à maille kilométrique. A la lecture de cette carte, la structure du Massif du Champ-du-Feu pourrait se schématiser ainsi : un môle de granits, à faible activité, formé aux dépens des terrains encaissants (môle du Champ-du-Feu) contre lequel viennent se heurter suivant le grand accident Lubine-Lalaye les granits des Vosges centrales. Au nord de l'accident, 4 massifs de granit porphyroïde à forte activité ont pris place suivant deux lignes privilégiées : Raon-Kagenfels, Senones-Natzwiller. Contrairement à ce que pensent les pétrographes, les mesures de radioactivité conduisent à séparer le massif de Barr—Andlau de celui de Natzwiller. Par contre, on peut rapprocher le filon géant du Kagenfels de la coulée rhyolitique du Rosskopf. Les mesures faites sur le massif de Dambach conduisant à classer ce massif parmi les granits « de métamorphisme » à faible activité du type du Champ-du-Feu plutôt que parmi les granits à forte activité des Vosges centrales.

Je remercie très vivement le Commissariat à l'Energie Atomique qui a bien voulu me confier ce travail et autoriser la présentation de ce mémoire. »

Le *Professeur Jung* (Paris) demande quelques précisions sur la géologie de certaines stations où la radioactivité est particulièrement forte.

La séance est levée à 12 h. 30.

NEUVIÈME SÉANCE

LUNDI, 20 SEPTEMBRE (matin)

Programme

16. — Communications scientifiques : Appareillages séismiques.

36. — *Mr. Beeman :* The SIE Magnetic Tape Recorder-Seismograph.

37. — *W. Hiller :* The Short Period Seismographs type « Stuttgart » with a simple and reliable magnetic Amplifier for Recording on Smoked Paper.

38. — *S. K. Chakrabarty* and *S. Sarkar :* Estimation of the Instrumental Constants of Electromagnetic Seismographs.

39. — *F. Press* and *M. Ewing :* Performance of Columbia University Three Component Seismographs To = 15, Tg=75 sec.

40. — *H. Benioff :* Quartz Crystal Clock.

41. — *H. Benioff :* Fused Quartz Earth Strain Meter.

18. — Visite de la station séismologique de Rome.

La séance est ouverte à 9 heures par le *Prof. Gutenberg* qui confie la présidence au *Rev. Dr. Ingram.*

16. Communications scientifiques : Appareillages séismiques

36. — La communication de *Mr. Beeman* intitulée : The SIE Magnetic Tape Recorder-Seismograph est présentée.

The SIE Magnetic Tape Recorder is designed primarily for the magnetic recording and storage of commercial exploration seismic data. The information is recorded on a single magnetic tape, or band, which is 4 inches wide and 40 inches long. The machine has 28 individually suspended recording heads which are used for both recording and

pickup of the data. This allows for the recording of 28 different phenomena simultaneously. In its practical use, it is suggested that 24 of the recording channels should be used for the seismic energy and the other 4 channels for timing and other required data.

For those who are interested in the electrical specifications — the SIE recorder is of the frequency modulated type where variations of the electrical amplitude of the signal are converted into frequency variations. The resultant frequency variations at a constant amplitude are then recorded on the tape. In order to play back or pickup the recorded information it is only necessary to amplify the recorded signals, clip them so that the amplitude will be constant — then feed to a discriminator which converts them back to amplitude variations. In this way all of the irregularities of the recording tape may be eliminated.

The SIE system differs from most other systems because it employs a special type of modulator-demodulator unit which is named a slope modulator. This special unit allows a very wide deviation rate (up to 75% for maximum modulation). This very special slope modulator combined with the fine mechanical drive system accounts for the very high signal to noise ratio of the SIE recorder. To elaborate further on in the electrical details, the tape speed is 7.5 inches per second. The center of the carrier frequency is 4000 cps. The signal to noise ratio for maximum modulation is approx. 60db. The total harmonic distortion is less than 1%. In regards to the last two items it may be seen that if magnetic recording is to be used for the broad band recording of seismic data and later played back under perhaps severe filtered conditions, these items become very important. These factors have been kept uppermost in the minds of the SIE engineers when designing this equipment.

While the SIE recorder is designed especially for commercial seismic exploration of the conventional type, it is by no means limited to this application — indeed it becomes a new and powerful tool in the hands of the experienced and imaginative geophysicist. — Following are just a few of the uses to which it may be put :

1. Recording of the seismic data virtually unfiltered and unmixed then being able to reproduce the record under many variations of filter and mixing techniques.

2. With only minor modification of the machine it may be seen that the visual data may be recorded with all of the fixed corrections removed from the record. It does not take much more imagination to visualize a record with the « step out » removed and to carry our imagination a bit further, we may be able to feed in another function and convert our time scale to depth (if we know the velocity), and thus plot a cross section almost automatically.

3. A machine may be modified to carry two or more tapes. These tapes may have been recorded in the field from the same shot point but at different depths. Adjustments may be made to the various sets of recording heads to account for these different shot hole depths, then the records added electrically to yield a record having a superior signal to noise ratio.

4. Another method may present itself, and that is one which we have termed « sequential » recording. This modification of the machine would mount 2 recording tapes running in syncronism. The seismic signal would be picked up from an array of geophones and amplified by a single channel and recorded one trace at a time on one of the tapes. A seismic disturbance (such as a small shot or a weight being dropped) would be made at some station and recorded. This process would be repeated several times in the adjacent area and each disturbance recorded on one channel of the tape recorder. Then these various channels would be added together and transferred to one of the channels on the second tape thus yielding one trace of a multitrace record. This system should yield a superior record in area where there is a high noise level caused by surface or new surface conditions.

5. A method of using a magnetic tape to eliminate phase distortion in a filtered seismic signal. — It can be shown, that if the seismic signal is recorded through a filter on to magnetic tape then played back through the same filter with the magnetic tape moving in the opposite direction, that the filter will be twice as effective, and that the phase shift caused by the filter will be 0.

6. It can also be seen that if the tape recorder is run at other speeds than that of recording, a frequency change will take place, which may be of practical advantage in resolving certain seismic problems.

7. Having the seismic data in reproducable form also spurs the imagination as to automatic data reduction. It is entirely possible that in the near future we may be able to make cross sections or even plot contour maps directly from our magnetic tapes.

There are probably many more uses to which magnetic tape may be put. We have tried to mention just a few. The SIE machine is not designed to accomplish all of the things mentioned above although various adaptions may be had to accomplish several of them. SIE will welcome any suggestion you may have for further uses of magnetic tape for seismic data. Its engineers stand ready to assist you in any problem you may have in applying this new tool to your particular needs.

37. — Le *Prof. W. Hiller* présente sa communication intitulée : The short-period Seismographs type « Stuttgart » with a simple and reliable magnetic Amplifier for recording on smoked Paper.

At the meeting in Brussels in 1951 I gave a short description of the short-period seismographs of type « Stuttgart » with galvanometric-photographic recording. With a pendulum of mass 1 kg, a reduced pendulum length of about 15 cm, and a free period of 1.5 sec. these seismographs are easy to adjust with the same constants in all three components and give a high magnification for ground periods of about one second. They have only one disadvantage, namely the high running costs for photographic paper with a paper speed of 60 mm/minute. For most seismological services it is impossible to maintain several stations equipped with such seismo-

graphs. On the other hand, in an earthquake region, it is necessary to have a dense net of seismographs with high magnification (resolution nr. 1 of the European Seismological Commission at Stuttgart in 1952).

Therefore we have tried — my Collaborator H. Berckhemer and myself — to find a simple and reliable solution to the problem of amplifying the weak electrical impulses of the seismograph and recording them mechanically. We have found a good way by employing the modern so-called magnetic amplifier (transductor) using no valves etc. All elements of the magnetic amplifier have a very long lifetime and are easy to adjust. This is important for outlying stations run by unskilled people.

I will not describe here the details of this magnetic amplifier; I will only mention that it was necessary to change the original inductive arrangement. We use an iron core with an air gap inside a coil in which runs a low frequency alternating current. When an earthquake occurs the size of the air gap is varied by the small movements between the pendulum boom and the pendulum frame. The changes in the resultant alternating current thus produced regulate the amplifier. The amplified electrical impulses go to a double bobbin suspended in a very strong magnetic field and cause mechanical registration on smoked paper. In this way the seismograph no longer records the velocity of ground movement but the ground movement itself. The seismograph is damped aperiodically. The time marks can be made in a very simple electrical way. The radio time signals are written directly on the records two or three times daily (paper speed 60 mm/minute). In this way one has the time correction with the same accuracy (one tenth of a second) as one can read the seismograms.

Since January 1954 at Stuttgart one seismograph of this type has been working without interruption. It gives the same magnification (about 2000-3000) as our big horizontal Wiechert seismograph with a pendulum mass of 17 tons; but the new seismographs are much easier to handle in all three components and the cost of making them is much less. Now complete sets of these seismographs have been made for our outlying stations at Ravensburg, Messstetten, Tübingen and Heidelberg.

Le texte complet de la communication du Prof. Hiller doit paraître dans la Revue « *Zeitschrift für Geophysik* ».

Le *Dr Grenet*, après avoir félicité le Prof. Hiller de cette réalisation, confirme qu'il est bon de pouvoir enregistrer avec des moyens très simples. Il pense qu'il serait désirable d'apporter encore des perfectionnements, afin d'obtenir des enregistrements rectilignes et non curvilignes.

Dr. Baxter asks: How is the magnification curve for long periods?

Prof. Hiller answers: It is very low.

38. — La communication de MM. *J. K. Chakrabarty* et *D. Sarkar* intitulée : « Estimation of the Instrumental Constants of Electromagnetic Seismographs » est déposée sur le bureau.

With the development of sensitive electromagnetic seismographs it is now possible to obtain a precise measurement of the ground motion associated with earthquakes or other disturbances but for that an accurate estimate of the instrumental constants viz. the period and damping of both the seismometers and galvanometers are required. The analytical expressions for ω, ωg, ε and εg have been given in a previous paper (1), but an accurate estimate of their magnitudes from that is not possible. We have also worked out the nature of the response curves when the pendulum is slightly displaced. In the present paper we have worked out theoretically the nature of the response curve and their variations with ε and εg for a Benioff instrument with known values of ω and ωg. These results have been compared with the experimental curves taken with two Benioff seismographs and the results are in excellent agreement with the theoretical curves. It has been suggested that these curves can be used in order to find out any changes in the instrumental constants and hence also on the nature of magnification curves. By simply recording the response to a « weight drop » and comparing the recorded curve with the theoretical curves given in the present paper it is possible to make an accurate estimate of ε and εg. ω and ωg, however, can be obtained by the usual methods. It has been suggested that in all routine measurements accurate estimates of ε, εg, ω, ωg are also given so that a proper comparison of the amplitudes and phases of different pulses are possible. It has been suggested that the weight-drop mechanism may be attached to all electro-magnetic seismographs and records of the response to the « weight drop » may be kept at least twice in a month as a routine.

39. — Le *Prof. F. Press* présente la communication intitulée : Performance of Columbia University Three Component Seismographs To = 15, Tg = 75 sec. by *F. Press* and *M. Ewing.*

Three component Columbia University long period seismographs have been in operation at Palisades for more than a year. Hitherto unrevealed long period components in body waves are often recorded. Examples of these phases are given and comparisons with records from standard seismographs are made. In addition, several new phases have tentatively been identified.

Prof. Hiller : Many stations should use this type of instruments. The influence of pressure changes on the horizontal components is probably due to the motion of the ground.

Le *Dr Grenet* fait remarquer qu'il avait construit à Tamanrasset un instrument semblable, comportant une compensation de la pression, cependant des oscillations dues aux variations de pression subsistaient. Il pense que, si le pendule est amorti à la valeur critique, il ne se trouve pas dans les meilleures conditions. Il vaudrait mieux amortir le pendule à 5 ou 6 fois la valeur critique, la courbe de grandissement devenant ainsi plus aplatie.

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(1) Chakrabarty, S. K. (1949), Bull. Seis. Soc. Amer., vol. 39, p. 205.

Prof. F. Press : It might also give too much magnification at short periods.

Le *Dr Grenet* répond : L'agrandissement maximum de mon instrument était trop faible (200) pour qu'on puisse observer ces ennuis.

40. — Prof. H. Benioff presents his paper : Quartz Crystal Clock.

A new form of quartz crystal clock of high precision has been developed for use in timing earthquakes. The time element is a 100 kilocycle per second quartz crystal oscillator. The crystal is cut in such a manner as to have a low temperature coefficient of frequency and it is housed in a constant temperature oven. The counter consists of a series of Wang saturable core transformers known as Perma-Memory Multiple Scalers, and operates for six million counts before repeating. It delivers an output impulse once per minute having a duration of 10 microseconds. A pulse lengthening circuit is provided for increasing the output pulse duration to approximately 1 second for operation of the relay which delivers current to the seismograph time markers and which drives an I.B.M. minute-impulse clock for a visual indication of the time. The frequency stability of this clock is such that the deviation from the mean frequency does not exceed 1/10 second of time per week. The cost of this clock is less than that of a marine chronometer and it is anticipated that its maintenance cost will also be less than that of a marine chronometer.

This paper has been published in « *Advances in Geophysics* » Vol. 2, Academic Press, 125 E. 23 Street, New York 10.

Prof. F. Press : Is there a provision for a clock coming in to give the time if a tube fails ?

Prof. Benioff : Yes, this is the case after a few minutes.

Rev. Dr. Ingram : What is the price of such a clock ?

Prof. Benioff said it is less than that of a chronometer, because it is partly self-built.

41. — Prof. H. Benioff reads a second paper : Fused Quartz Earth Strain Meter.

An earth strain meter with a fused quartz indicator tube of 25 meters length has been installed in a tunnel situated in the mountains northeast of Pasadena. Secular strains are measured with a filar microscope reading to 0,001 millimeter corresponding to an earth strain of 4×10^{-8}. Dynamic strains are recorded photographically with a double bow-string optical mirror device having a magnification of 10.000. The resulting sensitivity is such that a trace amplitude of 1 millimeter corresponds to an earth strain of 4×10^{-9}. This sensitivity is sufficient to record the tidal strains of the earth as well as strains associated with long period earthquake waves.

This paper has been published in « *Advances for Geophysics,* Vol. 2, Academic Press, 125 E. 23 Street, New York 10.

Dr. De Bremaecker : Is this the same instrument as in Palomar ?

Prof. Benioff : Yes, but this one is only 1 m. deep and is equipped with a transducer.

Prof. Wadati : What is the diameter of the quartz tube ?

Prof. Benioff : 6 cm., the wall thickness is 0,5 cm.

La séance est levée à 10 h. 45 min.

18. Visite de la station séismologique de Rome

Les membres de l'Association de Séismologie sont accueillis vers 11 h. 15 à la Station séismologique de Rome par les *Prof. Medi, Caloi* et leurs collaborateurs.

La Station est située dans la cave de l'Institut Géophysique à l'intérieur de la Cité Universitaire.

L'équipement instrumental, installé dans une seule et très grande salle, comprend les séismographes suivants :

Deux séismographes originaux, N-S et E-W (périodes des pendules et des galvanomètres 24 sec. ca.).

Un jeu de Galitzine-Wilip Z, N-S et E-W (périodes 10 sec. environ).

Deux verticaux Wiechert de 80 et 1.300 kilos.

Deux horizontaux N-S et E-W Wiechert (200 kilos).

Un Wiechert astatique de 1.000 kilos.

Après la visite de la Station séismologique, les participants ont l'occasion de voir quelques autres installations : en particulier les bacs pour l'étude des seiches en modèle réduit et l'atelier de mécanique de précision.

La visite est terminée vers 12 h. 15 m.

DIXIÈME SÉANCE

LUNDI, 20 SEPTEMBRE (après-midi)

Séance commune avec l'Association Internationale de Magnétisme

Programme

16. — Communications scientifiques : Discussion on « Movements in the Earth's Core and Electrical Conductivity ».

42. — *Sir Edward Bullard :* Introduction.

43. — *K. E. Bullen :* Physical properties of the Earth's core.

44. — *H. C. Urey :* Energy sources in the core.

45. — *S. K. Runcorn :* Core motions and reversals of the geomagnetic field.

46. — *J. Coulomb :* The magnetic secular variation.

47. — *T. Rikitake :* Electrical conductivity of the core.

48. — *E. H. Vestine :* Relation between fluctuations of latitude and geomagnetism.

49. — *R. Revelle* and *W. Munk :* Evidence from the rotation of the earth.

La séance est ouverte à 14 heures en présence d'une très nombreuse assistance sous la présidence de *Sir Edward Bullard.*

Le compte rendu de la séance a été rédigé par le *Dr M. N. Hill,* Cambridge (Grande-Bretagne).

In his introductory paper, *Sir Edward Bullard* noted that it is only recently that anything became known about movements in the earth's core; the knowledge is still slight but there are probably several observable phenomena which are connected with such motions and there are good prospects of discovering their important features. The first suggestion of an observable effect due to motions in the core came from the time scale of the magnetic secular variation. Large changes, with their origin within the earth, occur in times of the order of a hundred years which is about a factor of 10^5 times less than the usual time scale for events in the solid part of the earth. For this reason it appears impossible that the secular variation, or any other rapidly changing phenomenon, can have its origin in the earth's mantle. The simplest method of accounting for the secular variation is to suppose that it is attributable to motions in the fluid core although there is, so far, no direct evidence of their existence.

The hypothesis of fluid motion raises many questions concerning the mechanical, thermal and electrical properties of the material of the core, and allows electrodynamical theories to be developed to explain not only the secular variations but also the origin of the earth's main magnetic field. A number of papers have been published by Bullard, W. M. Elsasser and others about these theories of the main field. These were not considered in detail at this discussion. Bullard pointed out, however, that the dynamo theory of the origin of the main fied provides a strong field within the core which does not normally reach to the surface. On the other hand the secular variations are produced by fluid motions which must be near the surface since otherwise the screening effect caused by the high electrical conductivity of the material of the core would prevent their being observed at the surface of the earth. Calculations have shown that eddies at the core surface cannot produce the observed effects unless the initial field is considerably greater than the main dipole field. Bullard suggested that this might occur where the strong field associated with the dynamo theory is brought to the surface of the core at those places where the material rises from within the core. This process is analogous to a theory of the magnetic field of sunspots and appeared more plausible than the model suggested by Coulomb later in the meeting.

Bullen's paper concerned the density, the pressure and the elastic constants in the lower mantle and in the inner and outer cores. At the surface of the outer core Bullen estimated that the density lies

between 9.4 and 11.5 g/cm^3 and increases to between 9.8 and 12.0 g/cm^3 at the base of the outer core. The comparable figures for the incompressibility are between 6.2 and 12.6 $\times$ 10^{12} dynes/cm^2 increasing to between 6.4 and 13.1 $\times$ 10^{12} dynes/cm^2, and for the pressure 1.35 $\times$ 10^6 kg/cm^2 increasing to 3.20 $\times$ 10^6 kg/cm^2. The rigidity is probably less than 10^{10} dynes/cm^2. At the base of the mantle the density appears to be 5.6 g/cm^3. At the centre of the earth Bullen estimated that the density is between 14.5 and 18.0 g/cm^3, the rigidity between 1.5 and 3.6 $\times$ 10^{12} dynes/cm^2, and the incompressibility about 17 $\times$ 10^{12} dynes/cm^2. The pressure at the centre probably lies between 3.6 and 4.0 $\times$ 10^6 kg/cm^2.

Bullen suggested that the most probable composition of the outer core is a mixture of iron and ultrabasic rock perhaps in the form of a high pressure modification. The inner core consists of material whose atomic number is at least equal to that of iron with the possibility of an accumulation of elements of higher atomic number.

Urey's paper concerned the distribution of radioactivity which for thermo-chemical reasons might be present in an iron core, and a consideration as to whether it might be adequate in quantity to maintain the adiabatic gradient which is the primary condition for convection. He concluded that Uranium and Thorium are not present in the core but that it was not inconceivable that the heating is caused by the presence of radioactive Potassium. He also suggested that it was incorrect to expect, as in earlier work, a similarity between the concentration of the radioactive elements U, Th and K in iron meteorites and in the earth's core. Finally Urey expressed extreme uncertainty concerning the presence of the radioactive elements in the core and suggested, as in an earlier paper, that a more likely source of energy for maintaining convection currents would come from a reduction in the gravitational potential energy of the earth as a result of progressive differentiation from a more uniform to a less uniform chemical composition.

In the discussion following Urey's paper Runcorn asked whether there was any evidence for the present transference of iron from the mantle to the core. This might provide, through the loss of gravitational potential energy, the heat required to maintain the fluid motions. Urey replied that this process might exist but that there was no evidence for it.

Runcorn's paper opened with a discussion of the electrical conductivity of the lower part of the mantle. He explained that the value could not exceed about 1 ohm^{-1}cm^{-1} since otherwise the sudden changes in rate of the secular variations would be obscured from the surface by electromagnetic induction. Runcorn also suggested that the irregular changes in the length of the day are caused by varying electric currents in the lower part of the mantle and their associated torques. These changes occur in times comparable with the changes in the rate of the secular variation, and this confirms that the conductivity cannot exceed a similar value. Further, if the conductivity were much less than 1 ohm^{-1}cm^{-1} then excessively high E.M.F.'s would be required to produce the variable currents.

Finally, Runcorn gave details of calculations from which he concluded that reversals of the earth's main dipole field could be pro-

duced by changes of distribution of fluid motions in the toroidal field. It would not be necessary to reverse the direction of the toroidal field.

Coulomb considered a non-rotating earth model whereby the secular variation and the non-dipole fields are produced by steady motions in the core of the form of a « champignon ». Because of the high electrical conductivity of the core the fields must be produced from the surface layer of such motions which would in effect crowd the dipole field into regions of convergence of the flow and disperse it in regions of divergence. The velocity of vertical motion in a column of cross section 100 km^2 which would be required to produce dipole fields of the order of magnitude of those observed would be 5 m/s. This is considerably, greater than velocities previously postulated but on the other hand Coulomb pointed out that Elsasser admits the existence of horizontal velocities at least of the order of 0.1 cm/s, which is the value which would be obtained for a layer 50 km thick at a distance of 1600 km from the ascending column. In the discussion following Coulomb's paper doubt was expressed as to whether vertical velocities of the suggested magnitude could exist.

Revelle and Munk discussed the irregular fluctuations in the rotation of the earth. They deduced that the annual variations in the length of the day and in the position of the axis of the earth's rotation relative to the earth's crust could not be associated with motions in the earth's core but rather with atmospheric changes. On the other hand they believed that the atmosphere could not account for all the variations taking place in the order of ten years, and by a process of elimination they concluded that the observed fluctuations in the length of the day were probably due to the transference of angular momentum from the core to the mantle. The variations in relative angular momentum agree in sign and magnitude with those inferred from the westward drift of the magnetic field discussed in Vestine's paper. The combined evidence indicates a differential velocity between the core and the mantle of 10—20 km/yr near the boundary at the equator. The slippage zone cannot be thick since otherwise the detailed features of the non-dipole field could not be observed at the surface. This places a useful upper limit to the viscosity of the core material and supports Bullard's conclusion that the viscous coupling between the core and the mantle is less than the electromagnetic coupling.

In the discussion following this paper *Bullard* said that the various estimates of the kinematic viscosity of the core covered the range 10^{-3} to 10^{7} cm^2. s^{-1}. He favoured a value of 10^{-3} cm^2. s^{-1} and considered there was no necessity to exceed a value 1 cm^2. s^{-1}. *Sir Harold Jeffreys* replied that the nutation changes give an indication of a much higher value which might be adequate for viscous coupling between the core and mantle. T. Gold questioned the validity of Jeffrey's method of obtaining this higher value.

Rikitake's paper was concerned with the determination of the electrical conductivity of the core supposing that the currents which produce the secular variations are no greater than those required by a dynamo theory to produce the main field. If an upper limit

to the electrical currents is set then for an observable magnetic effect at the surface of the earth, there is an upper limit to the conductivity of the core. This is because of the cancelling effect of the field of the primary current which will result from the induced secondary currents producing the fields which become more nearly equal to that of the primary current as the conductivity increases. Rikitake estimates that from these considerations the conductivity must be less than 10^{4}ohm^{-1}cm^{-1}, a figure compatible with the result required by the physics of metallic iron under high temperature and pressure. In this paper Rikitake did not consider the magneto-hydrodynamic effect.

Le texte des communications ci-dessus a été publié dans les « *Annales de Géophysique* », Vol. 11, Paris 1955, pp. 49-109, et constitue le **fascicule 11 bis** des Comptes Rendus des Assemblées Générales de l'Association de Séismologie et de Physique de l'Intérieur de la Terre.

ONZIÈME SÉANCE

MARDI, 21 SEPTEMBRE (matin)

Séance commune avec l'Association de Volcanologie

Programme

16. — Communications scientifiques : Constitution de la terre — Dissipation de l'énergie dans la terre.

50. — *H. Menzel :* Recherches sur la propagation des ondes dans un milieu imparfaitement élastique.

51. — *R. Stoneley :* Rayleigh Waves in a Medium with two Surface Layers (Second Paper).

52. — *L. B. Slichter :* Seismic Interpretation Theory for an elastic Earth.

53. — *M. Bath :* The Density Ratio at the Boundary of the Earth's core.

54. — *L. Mintrop :* On the Balance of Pressure in the Earth's crust.

55. — *E. Perri :* Détermination des constantes élastiques des matériaux de la croûte terrestre par l'enregistrement des ondes élastiques superficielles.

55bis. — *P. Caloi* et *M. C. Spadea :* Diminution du module élastique dans des roches en contact avec des bassins hydrauliques artificiels.

La séance est ouverte à 9 heures.

16. Communications scientifiques : Constitution de la terre - Dissipation de l'énergie dans la terre

50. — Le *Professeur H. Menzel* présente sa communication intitulée : Recherches sur la propagation des ondes dans un milieu imparfaitement élastique.

La détermination des équations de la théorie de l'élasticité avec l'aide des théorèmes fondamentaux de la thermodynamique est un problème important qui peut uniquement être résolu dans le cas des phénomènes adiabatiques et des isothermes. Dans tous les autres cas, on se heurte à de notables difficultés mathématiques. On peut alors tout au plus proposer, pour l'équation fondamentale de la théorie de l'élasticité, une équation différentielle ayant les propriétés d'une formule d'interpolation. Dans le cas de processus très rapidement variables, elle doit se confondre avec l'équation fondamentale de l'élasticité des phénomènes adiabatiques. D'autre part pour des processus très lents, elle doit représenter de façon approchée l'équation fondamentale des phénomènes isothermes. L'équation proposée par Nakamura répond à ces conditions, mais non celle de la « visco-élasticité ». Si on utilise des résultats de Jeffreys, il est possible de réduire à une seule le nombre des constantes introduites par Nakamura. Dans un cas il a été possible d'en évaluer l'ordre de grandeur.

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques, fascicule N° 19.*

Sir Harold Jeffreys : The formula, as originally developed for layers near the surface, has a small second order term for λ' but the importance of this term increases to 10% at greater depths in the mantle.

Dr. M. Bath : For short periods we use the coefficients of adiabatic compressibility, for long periods the coefficients of isothermal compressibility. Where are the limits ?

Prof. Menzel : There are none, one goes into the other.

Dr. Bath : For a 5 sec. period, should one use the adiabatic coefficients ?

Prof. Menzel : No, the isothermal ones.

Prof. Benioff : There is a whole group of absorption constants which vary with the period (relaxation constants) from the millisecond range to millions of years.

Prof. Menzel : By integrating the equation one can obtain a curve of ε vs. frequency.

Prof. Benioff : There is a whole group of ε

Prof. Bullen : Would it be easier to use constants other than the

Lamé parameters : the incompressibility and the deviation tensors, for instance ?

Prof. Benioff : There are a few experimental data. Zenner's book discusses the matter further.

51. — Le *Dr. Stoneley* présente sa communication intitulée : Rayleigh Waves in a Medium with Two Surface Layers (Second Paper).

This communication deals with the propagation of Rayleigh waves in a uniform medium (3), corresponding to ultrabasic rock, with a Surface layer (1), of thickness T_1, and of approximately granitic composition, below which is a basic layer (2), of thickness T_2. The wave-velocity equation is obtained by straightforward but rather tedious analysis, as a determinantal equation of degree 10. Numerical solutions of the dispersion curves have been computed by the Electronic calculator at the Mathematical Laboratory, Cambridge, for the three cases

$$T_1 = T_2 \; ; \; T_2 = \tfrac{1}{2}T_1 \; ; \; T_2 = \tfrac{1}{3}T_1$$

that seem of seismological interest, and the curves of group-velocity against reciprocal of wave-length have been found by numerical differentiation. All three curves show a minimum group-velocity. Applied to Rohrbach's data on Rayleigh waves across the continents of Europe and Asia the curves fit the approximate empirical relation $2.5\ T_1 + T_2 = 100$ km; this value of 100 km is rather larger than that indicated by observations of Love waves.

Le texte complet de la communication du Dr. R. Stoneley doit paraître dans *Monthly Notices of the Royal Astron. Soc.* (Geophysical Supplement, Vol. VII).

Prof. Gutenberg : If T_2 is big enough there may be 2 minima. This would be interesting in case of a low velocity layer, when the source is in the low velocity layer.

Dr. F. Press : The location of the source is unimportant.

Sir Edward Bullard : What does the computing machine do ?

Dr. Stoneley : The machine calculates the elements of the determinant and the determinant itself.

Prof. Gutenberg : We want the equation in a shape suitable for machines.

Prof. Bullen : What were the results from computations of thicknesses using Love waves ?

Dr. Stoneley : The thicknesses obtained are somewhat different.

Prof. Gutenberg : Amplitudes can give us more information than travel times.

52. — Le *Prof. L. B. Slichter* présente sa communication intitulée : Seismic Interpretation Theory for an Elastic Earth.

The seismic interpretation problem for an isotropic spherical earth is analyzed on the basis of elastic theory, under the assumption that the three independent elastic parameters are unknown continuous functions of the depth. It is shown that solutions for each of these three functions may be obtained in the form of Taylor's

series. The problem is treated for three types of symmetrical excitation conditions on the free surface, — (1) a shear-source of type $\rho_{n\varphi}$ only (2); a pressure distribution with vanishing surface shear-stress (3); an excitation consisting of pressure in combination with surface shear-stress of type $\rho_{r\theta}$. In each case the excitation functions are arbitrary functions of time. It is assumed that the associated components of surface displacement over the sphere are known from available observations, as functions of time. Thus, the complete information contained in seismic records is used in the proposed interpretation process, without need of selecting, identifying, and assigning arrival-times to specific events on the records. The two static elastic parameters may theoretically be determined from observations at a single frequency, including the frequency zero, or static case. The determination of the dynamic elastic parameter requires the use of at least two different frequencies.

Algebraic checks are obtained by comparing the general solutions with the corresponding results for two special cases in which the elastic parameters vary in a prescribed manner in the interior of the sphere. In both these cases treatment by the classical ray-path method of interpretation is excluded, because the wave-velocity decreases with depth. Furthermore, the ray-path method (which is essentially a method of geometrical optics) would fail to distinguish between the two examples in any case, since the velocity function is the same in both, although the elastic parameters differ. In contrast to the valuable ray-path method, the analytical procedures in the present solution of the elastic problem are prohibitively cumbersome. Practical application of elastic theory to the direct interpretation of seismograms requires further development of the theory with probable utilization of modern high-speed computing methods (1).

Le texte complet de la communication du Prof. Slichter a paru en langue anglaise : L. B. Slichter, Seismic Interpretation Theory for an Elastic Earth, *Proceedings of the Royal Society*, A, Vol. 224 pp. 43-63, 1954.

Prof Gutenberg : This paper shows a prototype of methods which will have to be used in the future.

Dr. Pekeris : In the future it will be possible to obtain the elastic constants and the density, provided one has the amplitudes as well; by using times only the solution is not unique. In an analogous problem of scattering of a potential the solution is not unique due to the restrictions on what we can determine.

Prof. Gutenberg points out the importance of amplitudes in the bulletins of the stations in order to determine phases, especially for P and S and surface waves of 20 sec. period.

Sir Edward Bullard : In this case we have the phase relation whereas this is not true in Xray scattering or in electron scattering. The possibility of using data from stations where the ray method is not usable may be illusory because only diffracted rays get there.

(1) The author takes pleasure in acknowledging the assistance in this work provided by a Research Fellowship Grant from Rockfeller Foundation.

Dr. Stoneley : The method is very elegant but I wonder whether or not the continuity conditions might put severe limitations on it.

Dr. Slichter : No, because only Dirichlet's conditions have to be satisfied.

Dr. Gaskell : How much of the earth needs to be considered before the sphericity effects become really important ?

Dr. Slichter : The question is not easily solved.

Prof. Gutenberg : What is the effect of ellipticity on P" ?

Dr Slichter : As no provision has yet been made for the difference between continents and oceans and as this effect would overshadow the ellipticity one this is immaterial.

53. — Le *Dr. M. Bath* présente sa communication intitulée : The Density Ratio at the Boundary of the Earth's core.

A theoretical study is made of the behaviour of a P wave incident from the mantle on the boundary of the earth's core, with special reference to phase reversals. The dependence of phase changes on the density ratio or the ratio of Lamé's elastic parameters is demonstrated. For instance, for $\frac{\rho'}{\rho} = 1$ (no first-order density discontinuity) there is a change of phase both for $e < 10^\circ$ and for $e > 55^\circ$ (e = the angle of emergence at the core), whereas for $\frac{\rho'}{\rho} \geqslant 1.7$ there is a change of phase only for $e < 6.2^\circ$. Observations of PcP waves around epicentral distance = 30° prove conclusively that there is a first-order density discontinuity at the core boundary. They also show that $\frac{\lambda'}{\lambda + 2\mu} > 0.34$. A method for determining the density ratio by more complete observations of PcP is indicated.

The complete text of this paper has been published in « *Tellus* », Vol. 6, N° 4, 3 figs., Stockholm 1954.

Dr. De Bremaecker: The shock should be perfectly known because amplitudes depend on the direction.

Sir Harold Jeffreys : PcP should vanish at different distances with varying density ratios at the core.

Prof. Bullen : The density ratio is interesting and it seems that there has to be a density contrast.

Prof. Bullard : Is PcP known from Pacific explosions ?

Dr. Press : Is it the experience that ScS is small in transverse components ?

Prof. Gutenberg : It is big up to 30°, then it is obliterated by other phases. It is never a very long period wave. This is a remarkable fact, which shows that the transition between the core and the mantle is sharp.

Prof. Benioff : Maybe viscous relaxation plays a role.

Rev. Dr. Ingram : The direction of motion of PcP is important : it may throw more light on the problem.

54. — Le *Prof. Mintrop* présente sa communication intitulée : On the Balance of Pressure in the Earth's Crust.

The hypothesis of *Airy* that the mountains are floating in a plastic substratum has been and will continue to be of high value in the isostatic reduction of gravity measurements. But, this hypothesis has no constitutive worth, as in such reduction-calculations variable assumptions are made of the thickness of the solid crust, the configuration of the fictitious root of mountains, differences in density between the material of the root and of the substratum. *Airy* himself has never claimed to have found the real reason for the negative Bouguer-Anomalies in mountain ranges, nor has he tried to prove the validity of his hypothesis. Many years later seismologists believed to have found indications of roots of mountains in delays of the first arrivals of earthquake-waves. In reworking the seismograms and time-distance-curves of such earthquakes the author did not find a sign of delays of the first arrivals.

The modern seismic exploration methods by using artificial earthquakes, generated by blastings, offer the possibility to decide between the hypothesis of *Airy* and the conviction of numerous authors (*Condamine, Boscovich, Hopkins, Bischof, Babbage, Reade, Dutton, Deely, Reid, Daly* and others) who believe that the mountains are forced up by the pressure of melting material in great depth. The negative Bouguer-Anomalies in mountain ranges could be explained in this way as well as by assuming mountain roots (1).

The European Association of Seismologists has proposed to arrange seismic profiles through the Alps and north and south of them. As Geologists and Geophysicists all over the world take the greatest interest in closing the hundred years' discussion about mountain roots, these profiles should be observed in the very next future.

Prof. Gutenberg : The delay from the Kern Co. shocks proved the existence of a root of the Sierra Nevada. The delay was of 3 sec. at Haiwee, 4 sec. at Tinemaha. Both the stations and the epicenter should be near the mountains in order for a delay to exist; the new data of Byerly in Northern California confirm this.

Prof. Caloi : En Italie, nous trouvons aussi une différence croissante entre P_n et P_g, différence que nous expliquons par les racines des montagnes dans le granite et dans le basalte ou dans le basalte seul.

Prof. Gutenberg : The pressure at various depths was recently calculated and at the lowest level of the roots there is no difference.

Dr. Cloos : From gravity result and seismic works the depth of the roots of the Alps on the North is not very great at all. Experiments will shortly take place : two tons of dynamite will be exploded in the northern Alps and reflections will be studied.

Prof. Jung : The minimum of gravity is not in the northern Alps but farther south where the roots should thus be.

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(1) Voir: L. Mintrop. *Die Hypothese von Airy verträgt sich nicht mit seismischen Beobachtungsergebnissen,* Bull. d'inform. U.G.G.I., 2e année, N° 2, 1953, pp. 225-229.

55. — Le *Dr. E. Perri* présente sa communication intitulée : Détermination des constantes élastiques des matériaux de la croûte terrestre par l'enregistrement des ondes élastiques superficielles.

Dans des expériences faites en 1939 à Fegino (Gênes), l'auteur avait pu observer une onde superficielle particulière (ε) laquelle se révèle lorsqu'on enregistre des explosions à faible distance et en a étudié la constitution et défini la théorie (1).

L'auteur montre qu'il est possible, en utilisant les enregistrements de cette perturbation superficielle, de déterminer les valeurs généralement inconnues des constantes élastiques λ et μ des roches siège de la propagation.

De ses expériences sur les schistes marneux éocènes du Ligurien, l'auteur en tire pour ces constantes des valeurs *très inférieures* à celles que l'on déduit par voie indirecte au moyen de calculs basés sur les vitesses, normalement plus élevées, des rayons séismiques des phases P ou S.

Toutefois, à partir de ces mêmes expériences, un calcul basé aussi sur la même méthode, conduit à des valeurs corrélatives pour le coefficient de Poisson (σ) qui ne diffèrent pas sensiblement de celles qui correspondent aux trajectoires profondes dans la croûte terrestre et sont aussi de l'ordre des coefficients déterminés expérimentalement pour les roches à structure cristalline.

55 *bis*. — *P. Caloi* et *M. C. Spadea :* Diminution du module élastique dans les roches en contact avec des bassins hydrauliques artificiels.

Depuis 1949 jusqu'à 1952, à la suite d'expériences successives conduites par la méthode séismique, on a constaté une diminution du module élastique du rocher sur le côté droit de la grande digue de Pieve di Cadore.

Une raison qui a pu déterminer cette diminution peut être recherchée dans l'augmentation de la porosité du rocher.

Auprès de la digue fonctionnent une station séismique et quelques couples de clinographes.

Les enregistrements obtenus pendant plusieurs années permettent de pouvoir conclure que sur le fond rocheux qui sert de lit à un grand bassin hydroélectrique — spécialement dans les parties où la digue est assise — un travail continuel d'ajustement est en action au premier remplissage et aux remplissages successifs. Ce travail est déterminé par la rupture de l'équilibre existant. La rupture de cet équilibre peut se traduire par de véritables petits tremblements de terre ou, en tout cas, par une myriade de petites secousses, qui intéressent la roche tout autour du barrage.

Cette action poursuivie pendant des années provoque dans le milieu rocheux d'innombrables petites lésions, qui tendent à augmenter sa porosité.

(1) Dr. E. Perri, *Determinazione delle costanti elastiche dei Materiali della crosta terrestre attraverso la registrazione di onde elastiche superficiali*, «Geofisica pura ed applicata », vol. 27, pp. 7-29, Milano 1954.

Le texte complet de la communication ci-dessus a paru en langue italienne dans « *Annali di Geofisica* » sous le titre : Decadimento del modulo elastico in roccia a contatto con bacini idrici artificiali, vol. VII - N° 4, 1954, pp. 563-583, 10 fig.

DOUZIÈME SÉANCE

MARDI, 21 SEPTEMBRE (après-midi)

Séance commune avec les Associations de Géodésie et de Volcanologie

Programme

16. — Communications scientifiques : Déformations actuelles; Isostasie.

56. — *Rapport de M. le Professeur Heiskanen :* Report on Isostasy.

57. — *Rapport de M. le Professeur Vening-Meinesz :* Déviations d'équilibre dans la Terre; proposition de contrôler les déformations actuelles.

58. — *V. V. Beloussov :* La structure interne et évolution de la Terre à la lumière des données géotectoniques.

59. — *P. Caloi* e *M. C. Spadea :* Prime indicazioni di registrazioni clinografiche ottenute in zona ad elevata sismicita.

60. — *J. T. Wilson :* Interpretation of the Geology of some Mountain and Shield Areas in Terms of the Contraction Hypothesis.

61. — *T. Hagiwara :* Observations of the Crustal Deformations by Means of Horizontal Pendulum Tiltmeters, Water-tube Tiltmeters, and Silicatube Extensometers at several Places *in Japan.*

62. — *A. L. Hales :* A Theory of the Formation of Ocean deeps.

63. — *W. H. Bucher :* The Pattern of orogenic belts, an essential element in a hypothesis of crustal deformation.

La séance est ouverte à 14 h. 30 m. sous la présidence de M. le *Prof. Vening-Meinesz* et en présence de M. le *Prof. Bäschlin,* Président de l'Association de Géodésie, de M. le *Prof. Gutenberg,* Président de l'Association de Séismologie.

16. Communications scientifiques : Déformations actuelles ; Isostasie

56. — Le *Professeur Heiskanen* distribue un important rapport sur l'isostasie et commente ce rapport qui sera publié par les soins de l'Association de Géodésie.

Aux questions soulevées par le Prof. Heiskanen et concernant la séismicité, le Prof. Jeffreys répond : Do seismologists have any preference for one or two layers ? It doesn't matter too much, we don't have too much certainty. It would be preferable to continue in the same manner as before with one layer.

Prof. Mintrop : So far, nothing can be said from seismological evidence. The European Seismological Commission will make seismic profiles through the Alps, in order to ascertain the structure under the Alps and the Po Valley.

Prof. Heiskanen : One other point I would like to mention : If we only use one discontinuity instead of two, the gravimetric depth is *slightly* less than the seismological depth.

Prof. Gutenberg : The depth of the Mohorovicic discontinuity such as indicated on page 4 of the report by Prof. Heiskanen gives extremes, it would vary between 10 and 50 km.

Prof. Vening-Meinesz : It is clearly understood that the crust is above the Mohorovicic discontinuity; this is not the thickness of the rigid crust; they have no fundamental relation. The lowest discontinuity must not be much below the depth of the rigid crust.

57. — Le *Professeur Vening-Meinesz* présente un mémorandum concernant les mouvements de la Terre.

Our globe is unstable and several earth-sciences are engaged in the study of its variations and internal movements and of the causes bringing them about. We may consider this as one of the most important fields of research of our Union.

It is curious that up to now one of the most promising lines of investigation has not yet been systematically dealt with. Since many years only a few nations as e. g. the U. S. and Japan have in a thorough way taken it up and have made splendid research in this field but in other cases it has not been sufficiently investigated. We have in view the geodetic measuring, at regular time-intervals of from 10 to 50 years, of relative positions in the horizontal sense or in elevation, also with regard to mean sealevel, in order to state possible variations. That in many cases seismic research would considerably assist the understanding of what is going on, is clear. Perhaps accurate gravity research, repeated at the same time-intervals, would likewise prove to be useful.

Besides the great value which such research would have for the knowledge of the processes going on in the earth, it is obvious that it is also of great importance for the geodetic services which thus obtain indications of the changes in data which often have been considered as perfectly stable. Changes in level are evidently also of great importance for hydrologic research and the services connected with it and the geological services may likewise obtain valuable new data and view-points. The amount of the displacements in horizontal or vertical sense is probably never more than a few cm/year and this puts fairly high requirements of accuracy for the observations. Repetition of astronomic position determinations will usually not come up to these requirements. Triangulations, accurate

traverse work and precise levellings will, even for time-intervals of not more than ten years, be able to give satisfactory results.

The object of this memorandum is to stimulate the general taking up of repeated geodetic measurements in all areas where such research would be likely to reveal changes. Two questions arise: first, where is such research desirable and second, in what way can it be carried out if also taking into account the desirability that the results can be coordinated with those in neighboring countries and areas.

As to the first point, the writer started by planning a recommendation with regard to the mobile zones of the Earth's crust where the geological and seismological data point to strong crustal movements. In studying the matter he came to the conclusion that movements not only occur in those belts but that they may also take place in other areas, even in areas belonging to the so called stable shields. In these latter cases they usually occur mainly in a vertical sense, as e. g. the vertical movements of the glacial rebound type with secondary movements caused by them in neighboring areas, but if the shield is intersected by a fault zone or by a zone of flexure, even relative movements in a horizontal sense are not impossible. For the purposes stated in the beginning it is, therefore, necessary to put the recommendation in a more general shape. The time-interval between repeated observations will often depend on the schedule chosen in connection with the second point. A correlation of schedules in neighboring areas is obviously desirable.

As to the second point, the ideal way would evidently be to make everywhere the observations at the same time as it is e. g. planned for a great part of the work done for the geophysical year. This will, however, put many geodetic services in a difficult position. The writer should wish here to mention the system adopted by the U. S. Coast and Geodetic Survey in California on which Mr. Whitten has given him valuable information. Beginning in the south of California the triangulation is, gradually going northward, repeated and finished in the north about ten years afterwards. This schedule is then again repeated and so on. In this way every part of the country gets once its turn during the time interval of ten years. This system has the great practical advantage to require only a moderate budget, continued throughout the whole time, instead of a great expense at intervals of ten years. A second advantage is that the work is thus continuously done in the same way by the same personnel.

The second country we have especially mentioned is Japan. It is also making a more or less continuous effort for achieving control of the earthcrust movements but is guided in its schedule of observations by the way special areas are affected by seismic catastrophies.

It may be advisable to appoint a commission of the I.A.G. or of the U.G.G.I. on this subject of repeated geodetic control of crustal movements. In case of areas where such movements may be especially suspected but where no geodetic survey is present or in a position for taking up the necessary measurements, this commission might report on the need of work to be done and on the possibility of other instances taking it up.

A la suite de la présentation de son mémorandum le *Prof. Vening-Meinesz* propose la résolution suivante :

Proposed Resolution on Earth Movements.

The Union of Geodesy and Geophysics resolves to recommend geodetic measurements, to be repeated at regular time-intervals, for determining relative changes of position of well chosen stations in the horizontal or the vertical sense, the stations to be chosen in areas where variations are suspected. The triangulations, traverses and precise levellings have to be made with sufficient accuracy for obtaining a precision of 1 mm/year in the mean yearly displacements during the time-interval between measurements and are to be repeated in as much as possible equal conditions.

Le *Prof. Morelli* suggère la répétition des mesures gravimétriques de haute précision qui doivent apporter des résultats nouveaux pour la discussion.

Le *Prof. Vening-Meinesz :* This is very worth while trying ; it ought to be done with an accuracy of 0.01 m/gal. Only triangulations can do what we want, i. e., a precision of a few mm. ; it cannot be obtained by astronomical determinations.

Dr. Hoskinson : In California a survey of 600 miles long has been made, numerous astronomical azimuths have been determined. The expenses amounted to $ 50.000 a year. Only the determination of very exact azimuths might be sufficient. We have found motions amounting to 25 mm. a year. Some lines have been observed three times now. No gravity work has been done so far. The question is whether to run profiles across or along the fault line. The vertical work has been essentially the same as the triangulation work. We have evidence of subsidence due to withdrawal of water for irrigation (or to withdrawal of oil in S. California) : 15 feet of subsidence in 20 years.

Prof. Benioff : The gravity profile should be across the fault near the end of the faults where the material may pile up at one end and be stretched at the other.

Prof. Tsuboi : In Japan 5000 gravimetric stations have been measured at 4 km interval. Gravimetric work is faster than levelling so that gravimetry can be repeated every 10 years, but not levelling. No changes in gravimetry have been observed yet.

Prof. Gutenberg : It is proposed that the resolution be adopted.

La résolution proposée par le *Prof. Vening-Meinesz* est adoptée à l'unanimité.

58. — Le *Dr. V. V. Beloussov* présente sa communication intitulée: La structure interne et évolution de la Terre à la lumière des données géotectoniques.

Lorsqu'on étudie l'évolution de la terre et sa structure interne on doit considérer non seulement les données géophysiques mais encore les mouvements verticaux primaires de l'écorce et les phénomènes

magmatiques. D'après les données géologiques le rôle essentiel appartient à la différentiation de la matière d'après la densité.

Les mouvements ondulatoires verticaux, accentués dans les géosynclinaux, beaucoup plus réduits dans les régions de plates-formes sont étroitement liés à des phénomènes magmatiques tant intrusifs qu'effusifs. Dans les zones de soulèvement on observe de préférence des manifestations de magmas acides (intrusions granitoïdes) dans les zones de subsidence au contraire il y a par compensation un mouvement descendant de matériel lourd qui s'épanche sous forme de coulées basiques.

La vitesse de différentiation de la matière doit diminuer avec la profondeur par suite d'une augmentation de la viscosité.

Les intenses mouvements ondulatoires des géosynclinaux doivent correspondre à une relativement rapide différentiation dans les couches les plus superficielles alors que les mouvements plus calmes des plates-formes sont en rapport avec une différentiation plus lente dans les couches plus profondes.

Il est intéressant de noter que les mouvements ondulatoires à faibles contrastes des plates-formes viennent s'étendre jusque dans les géosynclinaux montrant que la différentiation apparaît simultanément dans différentes couches.

Au cours des temps géologiques on a observé généralement l'extension des plates-formes aux dépens des géosynclinaux; l'explication peut en être donnée par l'extinction de la différentiation à l'« étage » supérieur, et sa persistance à l'« étage » inférieur (la puissance de l'étage supérieur étant d'au moins 100 km).

Le passage du géosynclinal à la plate-forme se présente comme un phénomène régulier tendant à établir un équilibre dans la distribution de la matière à l'intérieur du Globe. Cependant dans certaines régions (Tian Chan, Altai, Est de l'Afrique, par exemple) où le régime de plate-forme était établi depuis la fin du Paléozoïque on a observé une reprise de mouvement ondulatoire très intense. Ce phénomène d'« activation » des plates-formes montre que dans certains cas il peut y avoir des conditions — dont la cause est inconnue — capables de compromettre l'équilibre et de provoquer le renouvellement d'une différentiation intense en profondeur. On peut supposer toutefois que le phénomène de la différentiation « multiétagée » peut provoquer dans des conditions propices des inversions de densité entre les étages amenant au toit de l'étage inférieur des matières plus légères que celles du fond de l'étage supérieur. Un tel état des choses serait bien entendu instable et devrait tôt ou tard se terminer par une percée de la matière légère vers le haut et une poussée de la matière lourde vers le bas. Cela équivaudrait à un renouvellement de la différentiation et des courants de matière.

Un autre problème complexe est celui des pulsations de l'écorce terrestre. On peut supposer que ces pulsations sont provoquées par des variations périodiques de la température à l'intérieur de la Terre, variations qui affectent la vitesse de différentiation.

La différentiation de la matière du Globe est compliquée par la migration des éléments radioactifs qui se concentrent dans les lieux d'accumulation des produits acides. Cette redistribution doit entraî-

ner des différences de température et en particulier amener un certain refroidissement des régions subcorticales.

Les bassins océaniques sont de formation relativement jeune; cette formation s'est accompagnée d'une intense fragmentation de la croûte, éruption de grandes quantités de laves basiques et destruction de la couche granitique. Si on admet qu'il n'y avait au Paléozoïque aucun ou presque aucun océan profond sur la Terre on est obligé de poser le problème de l'augmentation de la quantité d'eau sur le Globe au cours des temps géologiques. Cette augmentation se serait faite aux dépens de la vapeur d'eau qui se dégage du magma. L'hydrosphère et l'atmosphère ont dû se constituer graduellement au cours de la différentiation de la matière terrestre. Les phénomènes tectoniques sont donc liés à des processus complexes dont le plus important est certainement la différentiation.

Le texte complet de la communication du Dr. V. V. Beloussov est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

59. — Le *Prof. Caloi* présente la communication intitulée : Prime indicazioni di registrazioni clinografiche ottenute in zona ad elevata sismicità par *P. Caloi* et *M. C. Spadea.*

Des deux côtés d'une surface de fracture existant dans la zone de Tolmezzo, localité fortement séismique, fonctionnent depuis plus de deux ans deux couples de photoclinographes.

Les mouvements angulaires enregistrés de l'automne 1952 à la fin de 1953, sont diamétralement opposés.

L'écoulement mutuel des couches, mis ainsi en évidence, s'arrêta totalement dans les premiers mois de 1954.

Puis s'est produite une courte période séismique de grande intensité, qui a eu ses plus importantes manifestations le 25 avril et le 16 mai 1954.

On est amené à lier le phénomène d'écoulement observé à la brusque activité séismique qui a suivi son arrêt.

L'énergie qui se trouvait d'abord libérée dans le lent mouvement d'écoulement s'est accumulée dans les couches profondes et a amené les brusques ruptures d'équilibre du 25 avril et du 16 mai 1954.

Si les phénomènes observés présentent réellement une relation de cause à effet, ce serait sans doute la première fois qu'une période séismique d'une certaine importance serait surprise dans sa phase de préparation.

Le texte complet de la communication ci-dessus est publié en langue italienne dans « *Annali di Geofisica* », Vol. VIII, N° 1, 1955, pp. 121-133, 8 fig.

60. — Le *Prof. J. T. Wilson* présente sa communication : Interprétation de la géologie de certaines étendues de montagnes et de boucliers en fonction de l'hypothèse de contraction.

On a fait jusqu'à présent, relativement à des minéraux tirés de boucliers, deux ou trois cents déterminations isotopiques d'âge, qui servent de guides pour l'interprétation d'une quantité beaucoup plus

grande de détails en cartographie géologique. Il est maintenant évident que les continents sont répartis en zones et qu'ils se sont agrandis grâce à un nouvel apport de matière acide venant des profondeurs.

Les noyaux des continents se sont tous formés il y a plus de deux mille millions d'années. Ce sont des étendues caractérisées par des roches vertes du type Keewatin, dans lesquelles la grande proportion de matières volcaniques est probablement due aux gradients à hautes températures qui prédominaient dans la terre aux premiers jours de son histoire.

Les zones formées plus tard sont des ceintures de montagnes dans lesquelles plusieurs des mêmes particularités peuvent être reconnues et classées, soit en arcs d'îles récents, en montagnes mûres, ou en ceintures de gneiss archéens érodées.

Les conséquences de la contraction ont maintenant été élaborées en une théorie physique par Scheidegger. La contraction fait l'objet de la présente étude afin de démontrer comment la géologie d'un certain nombre d'arcs types, de montagnes et de boucliers peut être expliquée en fonction de cette théorie physique.

Le texte complet de la communication du Prof. J. T. Wilson intitulée « Interpretation of the Geology of Some Mountain and Shield Areas in Terms of the Contraction Hypothesis » a paru sous le titre « The Development and Structure of the Earth's Crust » dans « *The Earth as a Planet* » (G. H. Kuiper, Editor), Chapter IV, pp. 138-214, 25 figs., University of Chicago Press, 1954.

61. — Le *Prof. Hagiwara* présente sa communication : Observations of the crustal deformations by means of horizontal Pendulum Tiltmeters, Water-Tube Tiltmeters, and Silica-Tube Extensometers at several Places in Japan.

It is well known that the crustal deformations which are going on at the present time were found out successfully by means of the revision of the precise leveling. On the other hand, an attempt to find out continuously the crustal deformation by observing the changes in inclination of the ground by means of the horizontal pendulum has been made for many years. However, this method was not successful, because the observations by means of the horizontal pendulum gave always such large secular changes in inclination that we could not believe them as a really existing deformation of the earth's crust. The secular changes in inclination which are expected from the results of the revision of precise leveling are far less than one second in arc a year in the region where the crustal deformation is actually going on, while the changes obtained with the horizontal pendulum, in many cases, exceeded several seconds in arc a year.

The success of the precise leveling must be due to the sufficient length of the distance between two bench marks. If we suppose that there exist small disturbances of a small wave length superposing on the main inclination of the ground, the precise leveling will measure the mean inclination angle between a long distance, while the horizontal pendulum will register the very local disturbances which give a large inclination because of their small wave length.

The water-tube tiltmeter with a length of 20 m. has been installed in the gallery bored horizontally through the mountain side and the

comparative measurement with the ordinary horizontal pendulum tiltmeters was continued for ten years. The result showed us that the water-tube tiltmeter with a sufficient length can be available as a detector of the slow deformation of the earth's crust.

According to this conclusion, the water-tube tiltmeters were installed in a horizontal gallery underground in three places in Japan. The extensometers made of silica-tube with a length of 10 to 25 m. were also set up in parallel with them. The precise leveling was repeated along the routes near the stations. Both results, of water-tube and of leveling, were compared. The results were satisfactory.

Le sujet traité par le Prof. Hagiwara a déjà fait l'objet des publications suivantes : Hagiwara (T.), Rikitake, (T.) and Yamada (J.), Observations of the Deformation of the Earth's Surface at Aburatsubo, Miura Peninsula, Part. I. *Bull. Earthquake Research Institute,* Vol. XXVI, Tokyo 1948, pp. 23-26 ; 6 fig., 2 photos ; Hagiwara (T.), Rikitake (T.), Kasahara (K.) and Yamada (J.), Part. II, *id.*, Vol. XXVII, Tokyo 1949, pp. 35-38, 4 fig., 1 photo ; Hagiwara (T.) Rikitake (T.), Kasahara (K.) and Yamada (J.), Part III, *id.*, Vol. XXVII, Tokyo 1949, pp. 39-44, 8 fig. ; Hagiwara (T.), Kasahara (K.), Yamada (J.) and Saito (S.), Part IV, *id.*, Vol. XXIX, Tokyo 1951, pp. 455-468, 11 fig.; Hagiwara (T.) and Kasahara (K.), Part V, *id.* Vol. XXIX, Tokyo 1951, pp. 557-561, 3 fig.

Des rapports ultérieurs paraîtront dans le « *Bulletin of the Earthquake Research Institute, Tokyo* ».

62. — *Prof. A. L. Hales* reads his paper : A Theory of the Formation of Ocean Deeps.

Investigation of the stress distribution in a cooling Earth shows that the stress-differences increase much more rapidly in relation to the strength at depths of 100 - 600 km. than in the crust. It is suggested that it is failure in this tension zone which determines the periodicity of orogenic phenomena. On this theory about two-thirds of the reduction in volume due to cooling is concentrated in the neighbourhood of the region of failure and results in the formation of troughs at the surface of the Earth. Assuming that the period between successive failures is of the order of 50 million years and that the troughs extend over two complete great circles the cross-sectional area of an ocean deep should be of the order of 350 km^2. Estimates of the cross-sectional area of the existing ocean deeps range from 100 to 350 km^2. Furthermore the strips of negative anomalies correspond to deficiences of mass which have about the same cross-sectional area when calculated in terms of a density of 3.3 gcm^{-3}.

The substance of the communication entitled « A Theory of the Formation of Ocean Deeps » presented by Dr. A. L. Hales is contained in two papers : 1° The Thermal Contraction Theory of Mountain Building, *Monthly Notices of the Royal Astronomical Society,* Geophysical Supplement, Vol. 6, pp. 458-466, 1 Fig., 1953 ; 2° The Thermal Contraction Theory of Mountain Building, *Monthly Notices of the Royal Astronomical Society,* Geophysical Supplement, Vol. 6. pp. 486-493, 2 Figs., 1953.

63. — *Prof. W. H. Bucher* presents his paper : The Pattern of orogenic belts, an essential element in a hypothesis of crustal deformation.

La séance est levée à 18 h. 15 m.

TREIZIEME SÉANCE

MARDI, 21 SEPTEMBRE (14 h. 30)

Programme

16. Communications scientifiques : Radioactivité (suite).

64. — *S. Deutsch, D. Hirschberg* et *E. Picciotto :* Mesure des âges géologiques par les halos pléochroïques.

65. — *N. Isaac, F. Koczy, E. Picciotto, G. Poulaert et S. Wilgain :* Les isotopes du thorium dans l'océan et les sédiments océaniques.

66. — *F. Koczy :* Teneur en radium de l'océan et des sédiments océaniques.

67. — *U. Aswathanarayana :* Some statistical Aspects of the Distribution of Radioactivity in the Salem Gneisses of Madras State.

68. — *U. Aswathanarayana :* Transfer of Radioactive Matter through Rocks by Diffusion.

69. — *F. G. Houtermans :* Anomalous Leads of Volcanic Origin.

70. — *S. F. Singer :* The Age of Meteorites.

La séance est ouverte à 14 h. 30.

16. Communications scientifiques : Radioactivité.

64. — Le *Professeur Picciotto* présente la communication intitulée : Mesure des âges géologiques par les halos pléochroïques par *S. Deutsch, D. Hirschberg* et *E. Picciotto.*

On a étudié la possibilité de déterminer l'âge géologique des roches cristallines par les halos pléochroïques. On associe la photométrie directe des halos et la mesure de la radioactivité α des inclusions par les émulsions photographiques nucléaires.

Les mesures ont été faites sur des lames minces. On a sélectionné les halos dans les biotites, autour d'inclusions plus grandes que 50 microns (émission α en couche épaisse).

Pour exprimer l'intensité du halo, nous avons considéré le « rayon » du halo et la densité optique moyenne le long d'un profil. Ce dernier paramètre s'est révélé être le plus intéressant.

Cette étude préliminaire a porté sur des roches granitiques intrusives appartenant aux orogenèses alpine, hercynienne et calédonienne (40, 250 et 310 millions d'années).

Les résultats obtenus justifient, dans les limites des erreurs expérimentales, les deux hypothèses admises dans ce travail, à savoir :

1) sensibilité égale pour toutes les biotites granitiques ;

2) observation de la loi de réciprocité.

La résolution de la méthode dépend surtout du rapport des âges. Nous avons pu séparer complètement les roches tertiaires des roches primaires. Le rapport des âges trouvé expérimentalement correspond au rapport attendu.

Le texte complet de cette communication doit être publié dans le *Bulletin of the Geological Society of America.*

Dr. Marble recalled the excellent measurements made on pleochroic halos by the late G. H. Henderson at Dalhousie University and suggested that these measurements be continued.

Prof. Houtermans asked whether biotite shows a solarization effect and Dr. Picciotto replied that this effect has been observed and one must guard against it in older rocks.

Dr. Verhoogen asked how sensitive the halos were to heat and Dr. Picciotto replied that experiments are in progress to check this matter.

65. — Le *Professeur Picciotto* présente la communication intitulée : Les isotopes du thorium dans l'océan et les sédiments océaniques par *N. Isaac, F. Koczy, E. Picciotto, G. Poulaert* et *S. Wilgain.*

On décrit une méthode radiochimique de mesure de Th - 230 (Io) en présence de Th - 227 (Rd Ac) et Th - 232 supposé en équilibre avec Th - 228 (Rd Th).

Les résultats définitifs des mesures de Io et Th - 232 sont présentés pour une dizaine d'échantillons prélevés dans des carottes d'argile rouge du Pacifique Central (expédition suédoise de l'Albatross).

La construction en Io est de l'ordre de 2.10^{-9} g Io/g sédiment sec dans les couches les plus superficielles mesurées et décroît avec la profondeur dans la carotte. La concentration moyenne en Th est de 6.10^{-6} g Th/g. D'après les mesures d'U de Hecht, on voit que l'Io peut être en excès d'un facteur 50 à 100 par rapport à l'équilibre radioactif avec U et que le rapport Th/U dans ces sédiments est du même ordre de grandeur que dans les autres roches en moyenne. En admettant que Th et Io sont précipités dans la même proportion, le rapport Io/Th serait le meilleur paramètre pour la chronologie des sédiments. Divers critères sont proposés pour la validité de cette méthode, l'un d'eux est la constance du rapport Io/Th dans l'océan et les sédiments. La sensibilité de la méthode utilisée est suffisante pour permettre la mesure de Io et Th dans l'eau de mer, sur un échantillon de quelques dizaines de litres. Une mesure préliminaire a été

effectuée sur l'eau du Skagerak qui a surtout permis de mettre la technique au point et de vérifier le niveau de contamination radioactive. Les concentrations en Io ont été trouvées inférieures à 10^{-10} g/cc, celles en Th RdTh correspondent à une teneur d'environ 2.10^{-11} g Th/cc en équilibre. On constate que l'Io est inférieur et le Th supérieur aux valeurs attendues d'après des considérations de bilan géochimique et d'après les teneurs en Ra connues dans l'océan. Diverses interprétations de cette divergence sont proposées, la plus probable est que

1) RdTh n'est pas en équilibre avec Th

2) Seul l'Io en solution ionique échangeable avec UX_1 dans les conditions de l'expérience a été mesuré et qu'il ne représente peut-être qu'une petite fraction de l'Io total de l'eau de mer.

Le texte complet de cette communication doit paraître dans le « *Bulletin of the Geological Society of America* ».

66. — Le *Dr. F. Koczy* présente la communication intitulée : Teneur en radium de l'océan et des sédiments océaniques.

Lors de l'expédition suédoise pour l'exploration des mers profondes, sous la direction du Professeur H. Pettersson, des échantillons d'eau de mer ont été prélevés à différentes profondeurs dans les océans Indien, Atlantique et Pacifique pour mesurer la concentration en Radium de l'eau de mer.

Les teneurs trouvées varient de 0,3 à 2.10^{-6} g Ra/ml. A quelques stations, la teneur en Radium augmente avec la profondeur. La teneur en surface est généralement la plus basse, variant de 0,3 à $0.8.10^{-16}$ g Ra/ml. Les valeurs les plus hautes ont été trouvées près du fond et un maximum intermédiaire se marque aux environs de 1000 m.

Les mesures de Radium dans les sédiments océaniques démontrent la présence d'un excès de Radium dans une couche superficielle de 50 cm dans l'Océan Pacifique et de 1 mètre dans l'Atlantique. La quantité totale de Ra en excès par rapport à l'Uranium du sédiment est presque constante et semble correspondre à l'équilibre avec l'Uranium contenu dans l'océan. La répartition du Radium en profondeur dans le sédiment est en général celle qu'on attend d'après l'hypothèse de précipitation de l'Ionium, mais elle est très irrégulière et montre plusieurs maxima. Les teneurs varient au total de 0,5 à 67.10^{-12} g Ra/g et sont relativement plus hautes dans les sédiments du Pacifique que dans ceux de l'Atlantique. Les causes de ces irrégularités pourraient être :

1) la migration du Radium dans le sédiment ;

2) les changements de la vitesse de sédimentation ;

3) les variations dans la précipitation de l'Ionium.

D'après les mesures directes de l'Ionium par Picciotto et ses collaborateurs, il semble que la première cause intervient d'une façon importante, mais il faudra plus de mesures pour tirer des conclusions.

En supposant que la concentration en U est restée constante dans l'eau de mer, on a déterminé pour chaque carotte la vitesse de sédimentation moyenne durant les derniers 300.000 à 500.000 ans, il ne

semble pas possible avec le Radium seulement de déterminer avec certitude la vitesse de sédimentation à chaque instant.

Le sujet traité par le Dr. F. Koczy a déjà fait l'objet des publications suivantes : Koczy (F.), Weitere Uranbestimmungen an Meerwasserproben, *Oesterr. Akad. Wiss. Math.-Naturw. Kl.* Abt. II a, *158*, 1950 ; Pettersson (H.) and Koczy (F.), Radioactive Elements in Ocean Waters and Sediments, pp. 115-127, *Nuclear Geology*, ed. Faul (H.) Willeys and Sons; Kröll V., The Distribution of Radium in deep-sea sediments, sous presse, Rep. Swed. Deep-sea Exp., Vol. 9, 1955; Koczy (F.), The Radium and Uranium content of Ocean-water, en préparation pour Rep. Swed. Deep-sea Exp., Vol. 9 ; Koczy (F.), Picciotto (E.), Poulaert (J.) and Wilgain (S.), Les Isotopes du Thorium dans l'eau de mer, en préparation pour *Geochimica et Cosmochimica Acta*, 1955.

Dr. Koczy's and Dr. Picciotto's papers were discussed jointly.

Dr. Marble pointed out that Piggot and Urry's cores were shorter, so that they could not obtain the lower maximum.

Dr. Koczy added that their samples were taken in the Atlantic where sedimentation is faster.

Dr. Stoneley asked what value was obtained for the coefficient of diffusion and Dr. Koczy replied that the value was somewhere around 10^{-7}—10^{-8} g/cm-sec., but that he was not quite certain.

Dr. Verhoogen asked whether the radium value was large enough to affect heat flow and Dr. Koczy said it was not.

Prof. Harrison Brown asked whether the radioactive contents of these sediments are in agreement with values one would obtain from the few available carbon ^{14} ages of cores, and Dr. Koczy replied that there is agreement, but that sedimentation may not be constant and very likely varies from point to point in the ocean.

Dr. Pettersson observed that American values for Uranium contents in seawater are greater than the results obtained in Vienna. He said that Dr. Karlik there thinks that it is a problem of standards and suggests an international exchange of standards. Differences in standards are thought to be due to Uranium adsorption on glass.

Prof. Harrison Brown said that isotopic lead analyses of sediment samples of the Pacific Ocean are significantly different from the isotopic lead analysis of a «Strombus geigus» obtained in the Atlantic Ocean. The origin of this difference is unknown, but, if real, offers the possibility of a tracer.

Prof. Houtermans observed that the marine leads are essentially the same as present-day lead in spite of the disequilibrium which exists in the Ocean. He thought that measurements of lead ^{210} would give interesting new results on the motion of waters and sediments and that they were easy to make.

Prof. Pettersson agreed that such measurements would be interesting.

67. — En l'absence du *Dr. U. Aswathanarayana,* le *Dr. Marble* lit le résumé de la communication intitulée : Some statistical Aspects of the Distribution of Radioactivity in the Salem Gneisses of Madras State.

Twenty-seven specimens of gneisses and associated rocks drawn from the Salem-Yercaud area of Madras State have been examined for their radioactivity, which has been computed from B — radiation impulses of a sample. The data which is obtained in the form of counts is then grouped into classes and the frequency distribution curve is drawn. It is found that the data pertaining to the Salem gneisses indicate a unimodal distribution and hence attempts are made to examine the nature of the distribution. Statistical computations indicate that grouping into classes of size 30 counts gives data which is very satisfactorily explained by the Poisson law as tested by the X^2 test of goodness of fit. It is suggested that this result constitutes additional evidence in favour of the surmise that some natural processes favour a Poisson distribution. Attention is drawn to the lack of pre-designed pattern in sampling and the consequent difficulty in computing the goodness of the estimate of the parameter of Poisson distribution.

68. — Le *Dr. Marble* lit également un deuxième mémoire du *Dr. U. Aswathanarayana :* Transfer of Radioactive Matter through Rocks by Diffusion.

An attempt is made in the course of this paper to apply the physical principles of diffusion in spherical shells to investigate the influence of batholithic intrusion on the radioactivity distribution patterns in the intruded country rocks. Starting with fundamental laws of diffusion, a mathematical process is developed to work out the quantity of matter added to any unit area of cross-section in the spherical shell. The importance of diffusion processes in the transfer of matter through rocks is critically examined and attention is drawn to the inadequacy of the data on the subject. The economic implications of the work on diffusional transfer of matter are mentioned and its limitations are pointed out.

Le texte complet des deux communications de M. U. Aswathanarayana est destiné à être inséré en langue anglaise dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

69. — Le *Professeur F. G. Houtermans* présente sa communication intitulée : Anomalous Leads of Volcanic Origin (1).

Dr. Farquhar has emphasized in his paper (1) on the «Variations of the Isotopic Constitutions of Common Lead» the importance of the so called «anomalous» types of common lead for the interpretation of the isotopic abundances of lead and the use of common lead for age determination of lead ores and the determination of

(1) A full account of these measurements by F. Begemann, W. Buser, J. Geiss, F. G. Houtermans has been published in *Nuovo Cimento,* vol. 11, pp. 663-673, 1954, entitled : Isotopenzusammensetzung und Radioaktivität von rezentem Vesuvblei.

the age of the earth's crust. The best known among these types of anomalous leads are those from Joplin (Mo.) *(2)* and those from Sudbury (1). He has shown that in the latter case we can distinguish between two types of isotopic abundances, one of which may be interpreted as having a model age of about 1800 x 10^6 y. and a present day ratio $\mu = U^{238}/Pb^{204} = 10$ for the mother rock of the ore in the well known Holmes' diagram *(3)*. The other type of the Sudbury galena has a ratio Pb^{206}/Pb^{204} between 22 and 26 corresponding to a «negative» model age up to -3000.10^6 y. and may only be understood as a mixture of common lead and radiogenic lead.

Our group in Berne has analyzed recent lead from cotunnite ($PbCl_2$) which is being formed continuously as a sublimation product from fumaroles of Mt. Vesuvius *(4)*. During the last years two places of formation of cotunnite are known, one on the inside of the Northern edge of the crater, one on the outside of the crater towards Boscotrecase. The isotopic abundances found for some of these samples are given in table I.

TABLE I

Sample	date of collection	$\frac{Pb^{206}}{Pb^{204}}$	$\frac{Pb^{207}}{Pb^{204}}$	$\frac{Pb^{208}}{Pb^{204}}$
cotunnite, Mt. Vesuvius crater	24.8.1952	19,19	15.80	39,62
cotunnite, Mt. Vesuvius towards Boscotrecase	3.7.1949	19,14	15,75	39,37

This type of lead turns out to be also «anomalous». Formally the model age calculated from our diagram is p = 200.10^6 y.

Since this lead is being formed at present, we may try to test the hypothesis of an admixture of radioactive lead by measuring its content of Pb^{210} (RaD) which has a half-life T = 22 y. Indeed volcanic lead is highly radioactive as has been found already by Zambonini *(5)*. A chemical and radioactive analysis of cotunnite has shown that it is at least 99,5% pure $PbCl_2$ and its activity is practically exclusively due to the presence of RaD and its successive products RaE and Po^{210}. The RaD- content could be determined within 1 percent for a number of samples collected between 1825 and July 1954. The initial activity at the date of collection for 12 samples measured up to now is 20 disintegrations of RaD per sec. and mg Pb. This figure has been remarkably constant within the past 129 years. We may assume that the date of collection in most cases coincides very closely with the date of formation for the samples of 1954. This has been proved experimentally by following in these the growth of Po^{210} by means of α — counting and for a sample collected on September 24th 1954 at the mouth of a Fumarole even by the growth of RaE after collection.

From the content in RaD we may calculate the uranium-equivalent in equilibrium with this amount in RaD per mg of lead and we may thus obtain a minimum value for the ratio $\mu = U^{238}/Pb^{204}$ in the magma in the interior of the crater. We find $\mu \geqslant 110$. On the other hand the isotopic abundances given above show that the lead in question has spent most of its history in an environment

with a ratio $\mu = 10$. We therefore are justified to consider the Pb from cotunnite as a mixture of recent ordinary rock lead ($\mu = 0$, $\mu \simeq 10$) with radiogenic lead and we may even determine a maximum value of age for the « Uranium mineral » inside Vesuvius. This follows from the ratio of RaD to the excess of Pb^{206} over the amount of Pb^{206} that would be present in corresponding ordinary recent lead. This age, which may be interpreted roughly as an upper limit for the age of the volcanic activity results as $T \leqslant 17$ m.y. Among the samples of cotunnite measured, however, one collected in 1907 shows a specific RaD activity of only 5 dps/mg Pb in contradiction with all the rest. The reason for the strange behaviour of this sample has to be investigated more closely in future.

The sublimation products of lead of volcanic origin give thus an explanation for the present formation of an anomalous Pb which may be controlled by its present day activity in RaD. It may well be that also other cases of anomalous isotopic abundances may be explained in a similar manner. Furthermore we think that the ratio Pb^{210}/Pb expressed by the specific activity of the lead is a very important figure for all cases of recently formed lead because it allows the experimental measurement of the present day minimum value of μ. In the special case of volcanic lead this figure seems to be an important datum for vulcanology in itself from which we may learn something about radioactive conditions in the volcanic magma, possible mutual connections between different volcanic areas etc. I should be very glad if we could obtain from other research-workers samples of recently formed lead minerals, especially those of volcanic origin, in order to extend this type of research to other volcanic areas.

Finally we wish to thank Prof. A. Scherillo, Prof. A. Parascandola and Mr. D. Bevilacqua from the University of Naples for putting at our disposal a number of cotunnite samples of various ages and the great help we got from them in collecting samples and doing this research.

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(4) F. Begemann, J. Geiss, F. G. Houtermans, W. Buser, Nuovo Cimento 11, 663 (1954).

(5) F. Zambonini, Rend. R. Accad. Linc. 975 (1907).

Le travail complet du Prof. Houtermans sera publié dans la Revue « *Nuovo Cimento* ».

Dr. Verhoogen asked whether a mechanism could be suggested for the change in the lead/uranium ratio and Prof. Houtermans replied that he couldn't suggest one really, but that there is reason to suspect such a change, sudden or continuous. The magma contains very little lead and may have lost lead. It is possible that such processes may explain some of the anomalous leads such as those of Sudbury.

Prof. Harrison Brown observed that among the common lead values the $\triangle^{208}/\triangle^{206}$ ratio is very nearly uniform after one substracts primeval lead. This shows a remarkable uniformity in the Th/U ratio, i.e., about 1 to 3.

70. — *Professor S. F. Singer* reads his paper : The Age of Meteorites.

The bombardment effects of cosmic rays on iron meteorites lead to the production of helium. In the calculations of the production it turns out that about 30 per cent is in the form of the usually rare helium-3 isotope. Large quantities of helium-3 have now been found experimentally in meteorites whose age previously had been very high if it is assumed that all of the helium is due to the decay of uranium.

Comparison of the helium-3 content with the calculated helium-3 production rate can be used to deduce the exposure time to cosmic rays; thus one obtains the probable date at which the meteorite was created and therefore the break-up of its parent planet. Typical « cosmic ray ages » are of the order of 5×10^9 years. These dates are in disagreement with the solidification ages deduced from the uranium helium method. It is shown from several independent arguments that the latter are likely to be in error because of leakage of the radiogenic helium which is formed at the boundaries of the crystal grains. The cosmic ray produced helium, however, does not escape since it is formed inside the crystal grains.

The subject matter of this paper entitled «The Age of Meteorites» has been published in two papers : *1°* « Meteorites and Cosmic Rays », *Nature,* vol. *170,* p. 728, 1952; *2°* « The Origin of Meteorites », *Scientific American,* vol. *191,* p. 36, 1954.

Dr. Picciotto said that preliminary studies with nuclear photographic emulsions show that radioactive materials in the meteorites Carbo and Tolucca are not homogeneously distributed. So far it has not been possible to determine the exact locus, because iron reacts with the emulsion.

Prof. Harrison Brown suggested that one may separate tehnite from chamossite by dilute acid in an effort to localize the radioactivity.

Dr. Picciotto observed that his figures indicate a radioactivity 10-15 times higher than expected from other analyses and this discrepancy must be investigated further.

Dr. Boato said that there is a large variation in total helium content of meteorites. Calculations show that the meteorite Mt. Ayliff contains 30×10^{-6} cc per g and the meteorite Carbo somewhat less.

Prof. Houtermans asked whether the theoretical figures are good enough to confirm the discrepancies observed experimentally. He suggested that there may have been heating at the time the body from which the meteorites are formed, broke up. Dr. Singer replied that errors are about 20 % and depend on the depth in the meteorite.

La séance est levée à 18 heures.

QUATORZIÈME SÉANCE

MERCREDI, 22 SEPTEMBRE (matin)

Programme

16. — Communications scientifiques : Géothermie.

71. — *A. E. Maxwell* and *R. Revelle :* Heat Flow through the Pacific Ocean Basin.

72. — *H. Miki :* Temperature in the Interior of the Earth.

73. — *J. A. Jacobs :* The Thermal History of the Earth with Particular Reference to a number of Radioactive Earth Models.

74. — *R. J. Uffen :* The Application of Solid State Theory to the Determination of the Temperature in the Earth's Interior.

75. — *A. D. Misener :* Heat Flow Determinations at Resolute Bay, (T.N.-O) et Kemano (C.-B.), Canada.

76. — *J. Verhoogen :* Temperature Distribution in the Mantle.

77. — *H. C. Urey :* The Temperature of the Primitive Earth.

78. — *J. Goguel :* Bilan énergétique des explosions phréatiques.

79. — *L. Glangeaud :* Résultats énergétiques des éruptions sous-marines.

La séance est ouverte à 9 h. 10 m. sous la présidence du *professeur Jeffreys.*

16. Communications scientifiques : Géothermie

71. — Le *Professeur Maxwell* présente la communication intitulée : Heat Flow through the Pacific Ocean Basin par *A. E. Maxwell* et *R. Revelle.*

The results of measurements of the heat flow through the Pacific Ocean floor made on two Scripps Institution of Oceanography cruises in 1950 and 1952-53 have been evaluated. The oceanic heat flow was found to have a value similar to previously determined

continental measurements, the average value being 1.1×10^{-6} cal/cm^2 sec. The measurements have been made in widely separated areas in the Pacific and it is thought that they are representative of true oceanic values. Considerable variations have been found in individual measurements, possibly suggesting that anomalies of heat flow are present under the ocean and may represent previously undetected geophysical phenomena.

The heat flow values were determined by measuring separately the thermal gradient and thermal conductivity in the ocean bottom sediments. The sum of the errors of measurement is found from experimental and theoretical analyses to be of the order of ten percent. Investigations of the origin of the heat indicates that fluctuation of bottom water temperatures and processes occurring in the sediments are probably negligible, and that virtually all the heat must originate in the earth's mantle. Comparison of the oceanic with the continental heat flow suggests inconsistencies in the accepted values of the distribution of radioactive materials if we assume that heat transfer is taking place by molecular conduction. However, there should be a markedly higher temperature at depths of a few hundred kilometers under the oceans than under the continents. It is possible that convective processes may dominate in the oceanic area.

The heat flowing from the sea floor into the bottom and deep waters of the oceans should raise the temperature of those waters, and the observed small temperature gradients set a lower limit to the velocity of the meridional circulation.

Le travail de MM. Revelle et Maxwell doit être publié dans le « *Bulletin of the Geological Society of America* ».

Un résumé de ce travail sera inclus dans le *fascicule N° 19 des Publications du Bureau central séismologique international,* Série A, Travaux Scientifiques.

Dr. Birch : These measurements are remarkable and show a new aspect of temperature distribution. It is premature to take radioactivity for stony meteorites or ultrabasic rock. Another argument against deep distribution is that it necessitates a too high lateral value.

Prof. Jeffreys : Why was Q_s dismissed so easily ? There might be more Thorium and Uranium in the sediments.

Dr. Maxwell : The values found by previous workers were used.

Dr. Urey : What is the value used for H in the mantle ?

Dr. Maxwell : 10^{-14}.

Dr. Birch : This value is already obsolete.

Dr. Maxwell : This was only for illustration purposes.

A. Delegate : The Thorium content was found 25 higher than it was first thought from the Swedish Expedition.

Dr. Revelle : This latter value was used.

Dr. Jacobs : Results from purely physical computation agree with the resultats here presented.

Dr. Slichter : We might expect a somewhat dipolar situation in the distribution of heat.

Dr. Uffen : A good deal depends on conductivity and it was found at depth the conductivity might be ten times higher.

Prof. Jung : What was the initial temperature distribution ?

Dr. Maxwell : Linear.

Prof. Jung : From previous calculations hyperbolic and linear temperature distribution give very different results. This was for a flat earth.

Dr. Revelle : The depth to the Mohorovicic discontinuity seems to be the same on both sides of the Mendocino scarp. There must be differences in the mantle. There may be convection cells that would explain this.

Dr. Hales : Is it established that the gradient in the mantle is less than 3°/km ?

Prof. Bullard : It must be an upper limit from mathematical physical considerations (Clapeyron-Clausius equation).

Is it sure that the low-values are not due to deflections from verticality ?

Dr. Maxwell : It is quite sure.

Dr. Revelle : It is possible that we had only part penetration, but it is not likely to be the case.

72. — La communication du *Dr. H. Miki,* absent, est déposée sur le bureau. Cette communication est intitulée : « Temperature Distributions within the Earth » et a été publiée dans: *Journal of Physics of the Earth,* Vol. 2, N° 1, 1954, p. 1-3.

Several features of the temperature distribution within the earth's interior were derived from the modern theory of solids. The main results are as follows: (1) Grüneisen's parameter in the B-layer (33-413 km.) must be greater than 1.5. (2) Temperature in the D-layer (1000-2898 km.) increases almost linearly with increasing depth and its gradient depends on the mean atomic weight rather than on Grüneisen's parameter. For instance, the gradient is 1.79°/km. for A = 20 and 3.74°/km. for A = 40. (4) The temperature gradient in the B-layer decreases with increasing depth.

73. — Le *Dr. J. A. Jacobs* présente sa communication intitulée : The Thermal History of the Earth with Particular Reference to a number of Radioactive Earth Models.

L'auteur donne un aperçu des connaissances acquises jusqu'ici au sujet de la chaleur au sein de la terre. Ses observations portent surtout sur les conditions à l'intérieur du noyau, et il traite de la question concernant la formation de l'état physique du noyau intérieur. (Voir J. A. Jacobs, *Nature,* p. 172 et 297, 1953 ; 173 et 258, 1954).

La plupart des chercheurs dont les travaux ont porté sur la place importante de la radioactivité dans les questions géophysiques, ont supposé (pour simplifier le problème) que la chaleur se produit d'après une constante calorifique, bien que cette production ait diminué d'environ 50 p. 100 depuis que la terre existe. L'auteur traite

minutieusement de l'évolution de la chaleur de la terre, en tenant compte surtout de cet élément de temps. Il a subdivisé la question en deux : 1) celle du refroidissement d'une terre non radioactive à partir de sa température initiale, et 2) celle de l'échauffement graduel d'une terre radioactive à partir de la température zéro. La transmission de la chaleur en ce qui a trait à une terre radioactive a été résolue en équation numérique dans le cas de plusieurs maquettes différentes de la terre, au moyen du Ferut, calculateur électronique de l'Université de Toronto. On a évalué les températures de la terre prises à plusieurs niveaux de profondeur et la chaleur qui s'en dégage, ainsi que les températures et les degrés de chaleur qui existaient à plusieurs époques de l'évolution de la terre. L'auteur traite des suppositions faites dans la théorie et du caractère limitatif des résultats qui en découlent. Il suppose que les substances radioactives se trouvent dans des écorces à concentration différente bien qu'uniforme. Il a fait en sorte que le volume effectif de matière radioactive ne figure pas dans le détail des calculs. D'après des tables préparées, il est facile de noter par écrit une solution pour toute concentration voulue de matière radioactive contenue dans n'importe quelle des écorces de la maquette de la terre. Le résultat de ces calculs a permis à l'auteur de traiter, en peu de mots, de plusieurs sujets géophysiques : mouvements dans le noyau de la terre, théories relatives à l'orogénèse et degré de contraction par la chaleur.

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Dr. Urey : If you start with an Earth at the melting point, then there is convection and then the computations are wrong.

Dr. Jacobs : Yes, but the molten state does not persist.

Prof. Bullard : It is not proved that if part of it is molten and some heat is added all the rest melts.

Dr. Birch : If the melting curve is of this type we have a sink of heat and one can have a small radioactive heat without melting everything.

74. — *Prof. Uffen* présente sa communication intitulée : The Application of Solid State Theory to the Determination of the Temperature in the Earth's Interior.

L'auteur présente une méthode d'application de la théorie de l'état solide, des données sismiques et de la dispersion de la compacité de Bullen, méthode qui permettra, en principe, d'évaluer la répartition de la température dans la partie solide de l'intérieur de la terre. En prenant les équations semi-empiriques d'Einstein-Debye-Grüneisen relatives à l'état des solides, ou les équations de l'état basées sur la théorie de l'élasticité, il est possible d'obtenir des formules exprimant la « pression de la structure fenestrée » et la « pression thermale » d'un solide, pressions qu'il est possible d'évaluer en ce qui touche l'intérieur de la terre et dont l'ensemble doit égaler la somme des pressions qui s'exercent à une profondeur donnée, comme on l'obtient des données de Bullen. La pression thermale dépend de la température, tandis que la pression de la structure fenestrée en est

indépendante. Malheureusement l'appoint dépendant de la température est très faible, de sorte que la température évaluée à l'aide des données obtenues comporte une grosse marge d'erreur. Si l'on possède des évaluations assez exactes de la répartition de la température, dérivées d'autres domaines de recherches, on peut employer la méthode pour l'étude des propriétés physiques de la matière dont le manteau se compose.

Le texte complet de la communication du Prof. R. J. Uffen doit paraître ultérieurement dans « *Canadian Journal of Physics* ».

Prof. Jeffreys : The hump in the neighbourhood of 700 km. may be connected with the 20° discontinuity which is very difficult to establish seismologically.

Dr. Jacobs : It is difficult not to chase one's own tail. One has to make definite assumptions.

Prof. Gutenberg : There is no doubt about the existence of the hump, its end corresponds to rays emerging at 43°.

Dr. Birch : There are definite indications that the mantle is not uniform (from the moment of inertia). The potential function of Uffen is simple ; more realistic ones involve 3 terms and exponential terms.

Dr. Urey : In order to account for the observed hump it is only necessary to have rapid changes of density: changes of phases might be sufficient, is it not ?

Dr. Birch : Yes, but we have more than two components.

Dr. Urey : The point is that we do not have to have chemical changes.

Prof. Jeffreys : I am under the impression that Dr. Urey's ideas have changed.

Dr. Urey : Goldsmith's arguments are probably not correct and my ideas are always subject to revision.

Dr. Ramsey : I arrived at approximately the same conclusions, but the potential function used is not a sufficiently good approximation. The mean diameter of « ions » is very important, n varies between 2 and 12 and inside the Earth it may go up to 25. The fact that dK/dP is constant across the boundary seems to imply that n is constant there.

75. — *Dr. A. D. Misener* présente sa communication : Heat Flow Determinations at Resolute Bay, (T.N.-O) and Kemano (C.-B.), Canada.

Il ressort de mesures récentes des courants de chaleur qui se dégagent à la surface de la terre que leur quantité subit peut-être des variations régionales en fonction de l'évolution géologique de la région. Avant qu'il puisse être avantageux d'appliquer aux théories tectoniques le pouvoir des courants de chaleur et leurs variations, il faut avoir un grand nombre de mesures exactes prises en beaucoup d'endroits de la surface terrestre. Aux recherches précédentes faites à l'intérieur et près du bouclier canadien viennent de s'ajouter des mesures prises à Resolute Bay (74°41' de latitude nord et 94°51' de

longitude ouest), et au tunnel de Kemano (53°30' de latitude nord et à peu près 127°30' à 128° de longitude ouest).

Le plus vague des facteurs considérés dans toutes les mesures de courants de chaleur a consisté dans le résultat de la conductibilité thermique de la matière rocheuse parce qu'il a fallu obtenir un pouvoir type pour une région, tiré d'un certain nombre de petits échantillons, triés et soigneusement préparés. On a mis en œuvre une méthode permettant de mesurer avec exactitude la conductibilité thermique des roches *in situ* et qui donne un pouvoir plus caractéristique dans le cas d'un gros volume de roches. L'analyse mathématique de cette méthode d'examen en profondeur a été si bien perfectionnée qu'on peut confiner dans des limites précises toutes les erreurs qui se glissent du fait soit de la méthode par approximation mathématique soit de la technique expérimentale.

The complete text of this paper is to be published in two parts. The results from Resolute Bay will appear in a joint paper with Mr. P. Bremner in the publications of the « *Dominion Observatory of Canada* ». The results from Kemano, B. C., will be submitted to the *Transactions of the American Geophysical Union.*

Le *Dr. Birch* demande quelques précisions sur la nature géologique du sol ; l'auteur répond qu'il ne s'agit pas de sols superficiels, mais de roches compactes et en particulier de « shaly limestone ».

76. — Le *Dr. Verhoogen* présente sa communication intitulée : La distribution de température dans le manteau.

Le gradient thermique et la température dans la partie inférieure du manteau ont été estimés par diverses méthodes basées sur a), la température de fusion et sa variation en fonction de la pression, b) les propriétés élastiques du manteau et la variation en profondeur de Ks/ρ, c) les valeurs de la conductivité électrique obtenues par Price et par Runcorn, d) des considérations pétrologiques basées sur la température maximum des laves. Ces méthodes nécessitent l'emploi d'approximations différentes dans chaque cas ; elles semblent toutes indiquer un très faible gradient dans la partie inférieure du manteau et une température de l'ordre de 3000° K à la surface du noyau.

The complete text of this paper has been submitted for publication to the *Transactions of the American Geophysical Union.*

Prof. Jeffreys : My interest in the question dates back to 1916 when the data was very poor. In 1935 there was still no data on heat flow measurements or temperature gradients.

Dr. Jacobs : Verhoogen's results are in good agreement with my own.

Dr. Pekeris : How did you get α ?

Dr. Verhoogen : It is taken from Birch and Uffen.

Dr. Pekeris : What does Dr. Birch think of the uncertainties shown here ?

Dr. Birch : I think 4000 K is a better estimate ; I think the uncertainty is more of 1000 K.

Dr. Verhoogen : The uncertainty given is only from b_0..

Dr. Rittmann : How do you explain volcanism from these low figures ?

Dr. Verhoogen: I obtained these low values from volcanism also. I put the lava source at 100-200 km.

Dr. Rittmann : There is evidence of 1300° C at 80 km.

Dr. Verhoogen : Yes, this would give the right figure at the core boundary.

Dr. Uffen : Whether or not the inner core is solid also depends on whether there has been cooling and convection.

Prof. Bullard : Does the temperature of 1200 K prevail everywhere at that depth or only in local places ? If it is only in places it may be due to local processes.

Dr. Verhoogen : It prevails only where there is lava.

Dr. Rittmann : In very large areas and almost everywhere were Volcanoes occur wherever there is a chance for them, there is molten material.

77. — Le *Prof. H. C. Urey* présente sa communication intitulée : The Temperature of the Primitive Earth.

Since both the Chamberlain-Moulton theory, which postulated a low temperature origin for the earth, and the Jeans-Jeffreys theory, which assumed a high temperature origin, cannot be correct for reasons given by Russell some twenty years ago, it is well to consider the problem of the temperature of the primitive earth again.

The existence of an iron core within the earth has been regarded as proof that the earth had a high temperature origin, and if a core could not have been produced in any other way this argument would be final. The writer believes this is not the case. Bowen has argued that a thicker crust consisting of more granites and basalts than is observed must be expected if the earth had solidified from a molten condition. I find this argument a good one though explanations for the difficulties can be offered. Urey has shown that the elements which are markedly concentrated at the earth's surface have the common property of high solubility in water, and that elements of high volatility at even moderately high temperatures (1500° K) are not concentrated at the earth's surface. This indicates that the solubles, Cl, Br, I, and B, were concentrated at the earth's surface by liquid water and that the terminal stages of the earth's formation occured at low temperatures.

Recently the age of the earth has been revised, due to the work of Patterson, et al., as 4.5×10^9 years and the evidence indicates that the ratio of lead to uranium was changed from its primitive value of about 100 to a value of about 1 at the time indicated. This indicates that the lead as lead sulfide dissolved in troilite separated from the litophile elements uranium and thorium in the silicate phase while both phases were in a molten condition. This could have occurred while the earth was completely molten or in temporary molten pools such as once existed in the circular maria of the moon.

It seems probable that the earth, Mars and the moon all accumulated at generally low temperatures, with high temperatures pro-

duced locally and temporarily by the fall of large objects on the planets. It is suggested that the time between the earth's origin 4.5 x 10^9 years ago and the age calculated from the lead ores, namely 3.3 x 10^9 years, was possibly a period of reorganization of the earth along lines indicated by the studies of Vening-Meinesz.

The Paper « The Temperature of the Primitive Earth » by H. C. Urey is a review of two papers which have been published : the one, entitled « Concentration of Certain Elements at the Earth's Surface » in the *Proceedings of the Royal Society*, A vol. 219, pp. 281-292, 1953 and the other, « On the Dissipation of Gas and Volatilized Elements from Protoplanets », published in the *Astrophysical Journal*, Supplement Series, Vol. 1, 1954, pp. 147-173.

Prof. Jeffreys : It was believed that the Moon was separated from the Earth. Dr. Littleton has shown that this is impossible. It is possible that there has been separation between the formation of a planet and its breaking up. Since 1890 there has not been a good alternative to the contraction theory of mountain building, hence a cold Earth is difficult. It may be cold, heat up and contract while cooling.

Prof. Bullen : Urey's diagram on planets for P = o begs the question of no phase transformation. My point of view is that if there is a common mass for all the planets and one takes out Venus and the Earth's core one gets Mars and the Earth quite as they are as far as their densities go.

Prof. Urey : This is only a minor question. In either cases considered the abundance is too constant for a hot Earth.

Prof. Slichter : What is the temperature that you would allow for the formation of the Earth ?

Prof. Urey : First 50° K, then it may have increased and the metals were produced, but there was no fractionnation of importance in the more volatile elements of the non-volatile fraction.

Prof. Vening-Meinesz : I do not agree that the only theory of mountain formation is contraction. I think that the amount of evidence in favor of currents in the mantle is very large.

Dr. Rittmann : I agree that having compression and tension is evidence of currents.

Dr. Jacobs : What is Urey's opinion on the distribution of radioactive elements ?

Prof. Urey : Probably the concentration occurred largely by melting. I favor currents in the mantle. I do not think there is any radioactive material in the core.

Dr. Revelle : Do you allow a hotter outer Earth at any time ?

Prof. Urey : I have not thought the matter out.

78. — Le *Prof. Goguel* présente sa communication intitulée : Le mécanisme des explosions phréatiques.

L'auteur analyse le mécanisme des explosions phréatiques à la lumière des propriétés thermodynamiques de l'eau. Les gradients de

température (1° à 2° par mètre) nécessaires pour expliquer les explosions sont bien différents de ceux qu'on observe ordinairement. L'hypothèse selon laquelle la répartition des températures susceptible de conduire à une explosion phréatique résulterait d'un réchauffement général de l'écorce apparait comme très peu vraisemblable et on est conduit à chercher un mode d'échauffement local et accidentel, par exemple une intrusion de roche fondue se produisant à une profondeur relativement faible au milieu de terrains humides. En raison de leur porosité élevée, les accumulations de cendres volcaniques se prêtent particulièrement bien au déclenchement d'explosions phréatiques si des intrusions de magma frais se produisent à quelques centaines de mètres de profondeur.

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Dr. Rittmann : This mecanism of phreatic explosions is very interesting: the porosity must be very low, otherwise we have convection currents in the rock i. e., circulation and fumaroles. In this case the energy can not be stored up. On the other side there is evidence that phreatic explosions occur in case where there is an impervious covering layer.

Prof. Goguel points out that the best way would be to have alternate layers of porous and impervious material.

79. — Le *Prof. M. L. Glangeaud* présente sa communication intitulée : Les deux types de volcans sous-marins au point de vue de leur action energétique et géochimique.

S'appuyant sur les travaux du symposium de volcanologie d'Alger (section 15, fascicule 17, 1952) et sur ses propres recherches concernant les volcans sous-marins miocènes de l'Afrique du Nord, l'auteur a distingué deux catégories de manifestations volcaniques sous-marines.

Dans la première la profondeur est telle que la pression hydrostatique est nettement supérieure à celle du point critique de la vapeur d'eau. Dans ce cas (supracritique), les manifestations volcaniques n'offrent que peu de produits d'explosion (ejectamenta). L'énergie volcanique est employée en grande partie au soulèvement en coupole des premiers magmas à l'intérieur de ceux-ci et à d'importants échanges calorifiques et chimiques autour des centres volcaniques.

Au contraire, dans les volcans sous-marins ou sous-lacustres (infracritiques) de faible profondeur, les explosions phréatiques jouent un rôle important, les produits de projection sont abondants. Il s'édifie des cônes surélevés. Une grande partie de l'énergie est ici utilisée sous forme explosive. La zone de diffusion chimique, ainsi que la nature de cette diffusion paraît nettement différente de celle existant dans le cas précédent.

Dans les volcans profonds (supracritiques) la diffusion donne des formations siliceuses à radiolaires (radiolarite), des jaspes rouges accompagnées d'éléments où le manganèse et l'oxyde de fer jouent un rôle important. Dans les éruptions de faible profondeur l'activité bio-

logique s'associe à l'activité volcanologique. On observe généralement un grand développement de formations glauconieuses et calcaires.

Les études énergétiques et géochimiques doivent tenir compte de ces types très différents d'éruptions sous-marines.

Le *Prof. Goguel* fait remarquer que le point critique ne sera atteint qu'à plus de 2.000 m. si le mécanisme d'explosion est différent.

Le *Prof. Glangeaud* répond que la profondeur de 700 m. indiquée a été évaluée d'après la profondeur de la marne à globigérines.

Le *Dr. Rittmann* demande si les séries ophiolithiques sont vraiment des coulées.

Le *Prof. Glangeaud :* Ici ce sont des coulées.

La séance est levée à 12 h. 10.

QUINZIÈME SÉANCE

MERCREDI, 22 SEPTEMBRE (matin)

Programme

16. — Communications scientifiques : Microséismes.

80. — *Rev. Dr. J. Lynch :* Two-second Microseisms originating in the Great Lakes.

81. — *M. Bath :* Microseisms in the northernmost Atlantic.

82. — *A. Zatopek :* On the microseisms at Praha.

83. — *S. K. Chakrabarty* and *D. Sarkar :* Microseisms associated with Norwesters.

84. — *H. Menzel :* Investigations on Microseisms.

85. — *M. Bossolasco* et *A. Cavo :* Les microséismes à Gênes et leur dépendance de l'état de la mer : résultats de trois années d'observation.

86. — *J. H. Nanda* et *H. M. Iyer :* Microseisms at Cochin.

87. — *Dean S. Carder :* Microseisms at Bermuda.

88. — *M. Giorgi* et *E. Rosini :* I Microsismi di origine Tirrenica ed i nuclei di tendenza barometrica positiva.

19. — Examen de l'organisation de semaines internationales pour l'étude des microséismes.

La séance est ouverte à 9 h. 00 par le *Président Gutenberg* qui confie la direction de la séance au *Dr. M. Bath.*

16. Communications scientifiques : Microséismes

80. — Rev. *Dr. J. Lynch,* S. J., reads his paper : Two-second Microseisms originating in the Great Lakes.

Results of tripartite recordings in New York, Poughkeepsie West Park and Hot Springs (N. Carolina) indicate the Great Lakes as a source of two second frontal microseisms. To investigate the mechanism at this source, an instrument has been designed to record water vibrations in the Great Lakes simultaneously with ground vibrations on shore. This investigation is currently being pursued.

Le texte complet de cette communication est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Dr. Carder : I find confirmation of Father Lynch's idea at Lake Mead (Boulder Dam Reservoir) 1—1½ s microseisms are prevalent during high winds. Benioff's short period seismographs, 8-9 km from the lake are disturbed at this time and a like instrument 33 km. South of the Lake is also disturbed, but not as much. At Duluth, Minn., it was found that 0.8 to 1.0 sec. microseisms were quite prevalent even 100 km from Lake Superior. This disturbance is great enough to render the great Lakes area an inefficient locality of a highly sensitive short period seismograph.

Dr. Bath : I am pleased that an idea I advanced 3½ years ago, that microseisms do not necessarily originate from the storm centre and that the ocean floors are poor transmitters of microseisms, is gaining support.

A delegate : I would like to ask Father Lynch whether the pressure variations or compressional waves are the cause.

Rev. Dr. Lynch : The answer is not known.

81. — *Dr. M. Bath* presents his paper : Microseisms in the northernmost Atlantic.

Microseismic amplitudes and periods (4-8 sec) recorded at Scoresby-Sund, Reykjavik, Bergen, and Uppsala in seven different cases from the years 1949-1950 are studied. At all stations the polar air is of essential importance for the generation of microseisms, whereas there is in general no close connection with the cyclone centres themselves. A coast effect is of importance for Scandinavia, whereas the source of microseisms recorded at Scoresby-Sund is located over the open ocean within the polar air. Standing ocean waves may be of importance at the Norwegian coast but in many cases not on the open ocean. The microseismic waves propagate much farther over the continent than along the ocean bottom. The microseismic periods in Scandinavia vary generally in parallelism with the amplitudes, in Iceland and Greenland generally not. Period minima and rapid amplitude increases are observed in Scandinavia when cold fronts cross the Norvegian coast. There is no sign of microseismic barriers in the Atlantic outside Scandinavia, except for the different propagation of microseisms over the continent and the ocean bottom. The

microseisms at Scoresby-Sund have a regular group character; at the other stations they are generally continuous.

The complete text of the paper entitled « Comparison of microseisms in Greenland, Iceland and Scandinavia » has been published in *Tellus,* Vol. 5, N° 2, pp. 109-134, 11 figs., Stockholm 1953.

Le *Professeur Coulomb* fait des réserves sur la comparaison des inscriptions obtenues à Scoresby Sund et à Uppsala par des instruments très différents : d'une part des séismographes mécaniques dont le frottement peut jouer un rôle non négligeable, d'autre part des appareils Galitzine dont la sélectivité est forte pour les périodes considérées.

Dr. E. F. Baxter : A recent paper in the Bull. Seismog. Soc. Amer. showed that Rayleigh Waves from earthquakes approach from an angle which departs by as much as 30° from the great cercle path. If this refraction effect occurs for microseisms it would give the appearance of direction of approach from coastal margins.

Dr. M. Bath : This fact is of no consequence in Scandinavia (Paper of 1953).

Dr. Deacon suggested that the standing wave theory would usually imply that the source of microseisms would be behind the cyclone near the cold front. But we do not know much about the behaviour of the sea round a storm and there are some dangers in attempts to relate the microseism activity to the position of the isobars : the effect which the meteorological condition on the water has to be considered and experiments like these of Father Lynch are of particuliar value.

Prof. Hiller : At Stuttgart we have the largest amplitudes when a cold front approaches Norway.

Le *Professeur Coulomb* attire l'attention sur le travail d'Imbert sur les microséismes de l'Antarctique. Dans ce cas l'effet de côte est impossible en raison de la barrière de glace.

Le Dr. Hardtwig pense que dans le travail cité ci-dessus il n'est pas prouvé que les microséismes dans l'Antarctique ne proviennent pas d'autres côtes, de Nouvelle Zélande, par exemple.

82. — La communication du *Professeur A. Zatopek* intitulée: «On the microseisms at Praha » est déposée sur le bureau.

At the continental station of Praha (50°04'2 N, 14°25'0 E, h=225 m, Ordovician) the microseisms are recorded well from September to May, but are very weak during the summer. The present study is based on the data from the years 1948-1953 obtained from the records by Wiechert astatic horizontal pendulum and partly by torsion seismometers. A suitable graphical representation of periods and amplitudes allowed a continuous correlation of the variations of microseisms with synoptic charts and a comparison with the corresponding data of some European seismological stations. A number of individual cases (partly already analysed by other authors) with rapidly changing amplitudes were selected for a more detailed discussion with regard to the position, intensity, extension and movement of barometric lows, character and movement of fronts etc. Some sta-

tistical characteristics have been derived. The influence of winds passing over the station formed also a subject of investigation.

The main results may be summarized as follows :

1. Microseisms appear at Praha most frequently as groups of sinusoidal vibrations with periods between 3 and 9 sec. Their amplitudes, usually greater on the N component, do not exceed 3 microns. On the diagrams of the torsion seismometers periods of 2 sec., connected probably with local ground vibrations, have also been found. When microseisms are coming simultaneously from different sources, the inscription becomes less regular. Winds of westerly directions blowing over the station give rise to an irregular unrest due to the changing pressure of the wind against the front of the building.

2. The general character of microseismic variations with time is at Praha similar to that at De Bilt, Jena, Strasbourg and Uppsala; the individual differences consist in different distances from the sources, in a different influence of front systems and other regional or local factors. The great difference found between Praha and Rome indicates that the effects of Mediterranean regime of microseisms are very feeble at the station of Praha.

3. Synoptical changes in the frontal zone between Labrador, Greenland and Scandinavia are of the greatest importance for generating microseisms at Praha. The most abrupt increase of amplitudes is observed when deep cyclones with centres east of 30°W and north of 50°N are moving rapidly toward E or NE. Critical positions of the centres are in the region south and south-west of Iceland and over the sea between Iceland, Scotland and Scandinavia. Intense microseisms also appear when cyclone centres cross the northern part of the Baltic Sea. The cyclones outside these critical regions have, except for the extreme northern part of Norway, only little (if any) microseismic effect. The effect of fronts is mostly observed as irregular variations of amplitudes; the corresponding increase of amplitudes is generally small, excluding some cases of considerable periods and amplitudes (probably by effect of standing sea waves) observed during the front passages over the Baltic Sea. A part of shortperiodic microseisms (4-5 sec.) can be explained by the surf effect at the Norwegian coast. The problem of periods is very complicated. Generally (as known) microseismic periods increase with increasing amplitudes. Deep and extended active lows in the region of Iceland are usually connected with periods of 6 sec. and more.

4. A statistical survey of amplitudes shows for microseisms at Praha a diurnal variation with a minimum at midnight and a maximum after 12 h. MGT.

5. The form of summation curves of amplitudes allows a characterisation of the microseismic activity during different years, which might be useful for the study of the general circulation.

Le texte complet de cette communication est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

83. — La communication de MM. *S. K. Chakrabarty* et *D. Sarkar* intitulée : « Microseisms associated with Norwesters » est déposée sur le bureau.

Microseisms associated with atmospherie disturbances have been recorded in different parts of the world. While they appear to be similar in form, the period of the waves are different at different places. It has been observed that the microseisms recorded at Tokyo, associated with typhoons in the Japan sea have a period of about 3 secs., while those associated with typhoons in the Pacific Ocean have periods ranging between 3-5 secs. or 6-7 secs. depending on whether the typhoon is centered at the time of the record, to the west or east of Izu island. Similar differences have also been recorded by us. Even the monsoon microseisms or those associated with cyclones in the Arabian Sea recorded at Bombay have a period of 4-6 secs., but those produced by the disturbances in the Bay of Bengal have a prominent period of 2-3 secs. only. The present paper deals with microseisms associated with Norwesters, which are produced by an instability in the atmosphere and are quite frequent in the pre monsoon season (April-May). They differ from the cyclones mainly in the fact that they are produced over the land and at least in some cases appear to come over Calcutta from a North-Westerly direction and ultimately pass into the Bay of Bengal. We have recorded microseisms associated with these disturbances and it appears that when these disturbances are very near the observatory but still over the land, very feeble microseisms of short period (1.3-1.4 secs.) are recorded which after a short time disappear completely, but reappear only after the center of disturbance has crossed the coast and is far into the sea. The period of microseisms then gradually increases with time and the amplitude is also much higher although the distance of the center of disturbance has increased and its intensity has possibly decreased. Comparing these with the theoretical results of Biot and Press and Ewing, it has been shown that the period of the microseisms should increase linearly with the depth of the water below the center of disturbance, and the transmission of the microseismic waves is through the bed of the sea and is certainly not due to any surf action or beating of the high waves over steep coast. The variation of the wave periods gives an estimate of the depth of the continental shelf which is in agreement with the results deduced from other observations. The results also indicate that the microseismic waves of periods less than 2 secs. are either absent or have only a very small portion of the total energy. The analysis of the present paper shows that microseismic waves appearing from different regions can actually have different periods which depend on the depth of the water column just under the centre of the disturbance which produces the microseisms.

84. — Le *Professeur Menzel* présente sa communication intitulée: « Etude sur l'agitation microséismique » *).

*) Cette communication comprend outre les résultats du Prof. Menzel ceux obtenus par ses collaborateurs et contenus dans les publications suivantes :
Menzel (H.), Über die seismische Bodenunruhe in Norddeutschland. La semaine

Une méthode pour fixer les centres d'origine des microséismes sera interprétée.

Cette méthode est applicable, si les ondes des microséismes sont des ondes de Rayleigh. La question de la nature de ces ondes sera discutée. Un emploi de cette méthode sur un grand nombre de microséismes donne le résultat que les centres d'origine sont toujours situés au-dessus de la mer. La relation des amplitudes et des périodes des microséismes sont caractéristiques du centre origine. Les observations faites jusqu'à présent à Hambourg confirment que les causes des microséismes sont expliquées le mieux par la théorie de Longuet-Higgins. L'importance de ces recherches pour certaines questions géologiques est discutée.

Miss I. Lehmann : We have in Copenhague observed microseisms when storms are centered west of the line indicated as a barrier by Dr. Menzel. It happens quite often that storms centered south of Iceland stay at about the same place for some days.

Dr. F. Press : How are the measurements of swell made ?

Dr. M. Bath : I believe it is by visual observation from weather ships. They are more accurate than the usual weather observations of sea.

85. — Le *Professeur M. Bossolasco* présente la communication intitulée : « Les microséismes à Gênes et leur dépendance de l'état de la mer : résultats de trois années d'observations » par M. Bossolasco et A. Cavo.

L'enregistrement continu de l'état de la mer (houle) et des microséismes à Gênes pendant la période août 1951 - août 1954 (par les soins de l'Istituto Geofisico e Geodetico dell'Universita di Genova) a permis de relever une dépendance étroite entre les deux phénomènes : à une augmentation de la houle correspond en général une augmentation de l'activité microséismique; les coefficients de corrélation sont élevés.

Une analyse des microséismes engendrés par la houle à Gênes est traitée en rapport avec les conditions locales.

De l'ensemble de nos observations il résulte que dans les lieux situés au voisinage de la mer, les microséismes qui s'y observent ont comme cause principale l'état de la mer. Sans l'observation continue et détaillée de celle-ci, l'étude rationnelle des microséismes n'est pas possible.

Le mémoire détaillé paraîtra dans le vol. 32 de « *Geofisica pura e applicata* », 3e-4e trimestre de 1955.

Rev. Dr. Ingram remarks that they find that microseisms of a 2-3 secs. period are generated almost immediately by an on-shore wind, that is an East wind. It is not sure what is the mechanism. Further work is being done with a faster recorder to solve this problem.

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d'étude sur le problème des microséismes. Pontificiae Academiae Scientiarum Scripta Varia. 1952, pp. 223-233.

Westerhausen (H.), Über die Ortung mikroseismischer Unruheherde. Annali di Geofisica, vol. VII, 1954, pp. 71-124.

Westerhausen (H.) : Arch., Met., Geoph. u. Bioklim. Wien (im Druck).

Strobach (H.) : Inaugural-Dissertation, Hamburg (noch nicht veröffentlicht).

Dr. Bath asks of what period are microseisms ?

Le *Prof. Bossolasco* répond : 2-10 secondes.

86. — La communication intitulée : « Microseisms at Cochin by *J. N. Nanda* and *H. M. Iyer* » est déposée sur le bureau.

A seismographic station is set up at I.N.Physical Laboratory Cochin to study the nature of microseisms and to correlate the observations with general sea conditions there.

The microseism pendulum used is of the electromagnetic type of about 3 seconds period which was obtained from the Carnegie Institution of Washington D.C. The recording is done on tape at a very low speed and analysis is made by running the tape recorder faster and analysing signals by electrical means. Analysis shows large intensities between 3 and 6 seconds period. The period of sea waves nearby at that time was 12.8 seconds on the average. Three more microseisms stations of the same kind are planned for various points along the West coast of India.

Le texte complet de la communication de MM. J. N. Nanda et H. M. Iyer est destiné à être inséré dans les *Publications du Bureau Central séismologique international, Série A, Travaux Scientifiques,* fascicule n° 19.

87. — *Dr. Dean S. Carder* reads his paper : Microseisms at Bermuda.

From an examination of above normal microseisms recorded on the Bermuda Milne-Shaw seismograph over several hurricane and winter seasons, it was found that in all cases, if the periods were 4 to 5 seconds or if the microseisms were strong, they could be attributed indirectly to local weather conditions. 6 sec. period microseisms may have local or regional sources, and 7 to 10 sec. period microseisms may have local or distant sources. In every case, if the sources are from distances greater than a few hundred kilometers, the amplitudes are relatively small.

Fast moving hurricanes approaching the island will not produce microseisms until the storm is on or close to the island, but if the forward motion of the hurricane is slow, the resulting ocean swell may reach the island first, in which case the strength of the microseisms probably depends on the strength and period of possible opposing swells, either from the wake of earlier hurricanes or from extratropical sources.

Heavy microseisms may be produced when no tropical or extratropical storms are in the area but when winds are favorable for the production of opposing swells.

It was found that storm effects on the coast of Alaska were responsible for strong 7 to 9 second microseisms throughout North America and weak ones on Bermuda. The absorption rate across the continent was relatively low, and relatively high across the Northwest Atlantic. It was found that if the source is on either margin of the continent energy absorption over a 1000 km oceanic path is probably at least an order greater than over an equal continental path, the rate probably greater for the shorter periods.

There is evidence that the period increases slightly with distance over the first few hundred kilometers of an oceanic or a continental path, but beyond 1000 km, in each case, the increase of period with distance is negligible.

Period variations of storm microseisms at Bermuda are apparently independent of depth. A dependence on wind strengths, with perhaps a limiting factor governed by the depth of the ocean, has better support. If period does depend on wind strength, it may be because the ocean swell period is also dependent on wind strength together with the expanse of ocean exposed to the wind — but that microseisms are generated only if the same period ocean swells are oppositely directed or have strong oppositely directed components. That may be one reason why wind strength-period dependence fails at times.

The Longuet-Higgins theory of microseismic generation is supported.

The paper on « Microseisms at Bermuda, summarizing two papers entitled « Transmission of Microseisms across North America and the Western North Atlantic » and « Microseisms at Bermuda » were submitted for publication in the *Transactions of the American Geophysical Union.*

Prof. F. Press said that new Benioff seismographs at Bermuda show the same results as Dr. Carder has obtained. A hurricane itself does not produce microseisms, at Bermuda except as local effect. Either a hurricane does not generate microseisms in deep water or the elastic waves are greatly attenuated in crossing the deep ocean. Any theory of microseisms must explain this effect.

Dr. Deacon observed that the fact that the microseismic activity continues after the storm has gone gives a clear indication that sea waves play a significant part in the mechanism. The storm has gone, the winds have gone, only the wave travelling relatively slowly in from the ocean are left as a source of energy.

88. — Le *Professeur M. Giorgi* présente la communication intitulée : « Les microséismes d'origine tyrrhénienne », par MM. Giorgi et E. Rosini.

Nous avons déjà fait plusieurs publications à ce sujet, et nous nous sommes proposé d'étudier systématiquement les relations entre tempêtes microséismiques et perturbations atmosphériques, pour déterminer l'agent spécifique qui établit le rapport entre les deux séries de phénomènes.

Un des principes fondamentaux sur lequel nous avons basé nos recherches est le suivant : on ne peut pas faire un choix unilatéral et fragmentaire de la situation à étudier, en considérant seulement les quelques cas spéciaux, où la perturbation microséismique est plus évidente, si l'on veut examiner l'allure de quelques éléments météorologiques; il faut, au contraire, établir une comparaison systématique et continuelle entre l'activité microséismique et l'évolution du temps, pour obtenir un tableau complet des concordances et éventuellement des différences. Le deuxième principe fondamental est le suivant : l'étude météorologique ne peut pas se limiter à la consi-

dération de quelques éléments choisis a priori, mais il faut considérer l'évolution météorologique dans son ensemble, sans négliger aucune des données et des éléments que les météorologues élaborent au cours de leurs analyses. Seulement en partant de cette base et examinant une longue période de temps, on peut arriver à des conclusions qui seront objectives, parce que ce sera la recherche même qui les aura suggérées, et qui seront sûres, parce qu'elles se fonderont sur la réalité des situations.

Le matériel d'élaboration est le suivant : pour ce qui concerne les microséismes, on a étudié les enregistrements obtenus dans les Observatoires Séismiques de l'Istituto Nazionale di Geofisica et en particulier les enregistrements des séismographes électromagnétiques Galitzin et Galitzin-Wilip de périodes propres 25^{s} et 10^{s} fonctionnant à l'Observatoire de Rome et des séismographes des Observatoires de Padoue, Bologna, Messina et Catania. Pour ce qui concerne les situations météorologiques, on a eu à disposition toute la documentation graphique du Centre National des Prévisions du Service Météorologique de l'Aviation Militaire italienne, ainsi que les archives générales d'observation et d'enregistrement du même Service.

L'analyse ainsi effectuée pendant bien des années nous a permis d'arriver à des résultats que nous considérons sûrs et définitifs. Dans cette courte exposition orale il est possible seulement de donner quelques exemples rapides de la documentation recueillie, afin d'éclaircir les conclusions auxquelles nous sommes parvenus.

En première ligne, grâce à la richesse du matériel à notre disposition, il a été facile de constater la concordance entre les caractères morphologiques des tempêtes microséismiques et surtout leur période et le point géographique des perturbations météorologiques qui les produisent. Ceci nous a permis d'établir un rapport quantitatif entre la période des microséismes et la distance des zones dérangées. On a pu concentrer ainsi l'attention sur les rapports entre les enregistrements microséismiques de courte période, limitée à 4-5 secondes au plus, et les perturbations voisines, qui frappent la Mer Tyrrhénienne et les zones environnantes. Cela a permis d'utiliser complètement les observations météorologiques des stations italiennes, et partant d'examiner tous les aspects de la question; en outre, la proximité de la zone d'origine contribuait à rendre le rapport entre les microséismes et l'agent capable de les produire plus étroit et par conséquent plus facile à identifier. A cette fin, la comparaison entre les enregistrements obtenus dans les Observatoires Séismiques situés dans différentes régions d'Italie a été particulièrement significative.

Les résultats déduits de l'examen comparé de l'activité microséismique enregistrée dans les différents Observatoires et l'évolution simultanée des perturbations atmosphériques, — examen effectué, comme nous l'avons dit, pendant plusieurs années — peuvent être résumés de la manière suivante :

a) Le retard que l'on observe toujours entre le passage d'un centre de dépression, quand il existe, et le point d'origine d'une activité microséismique confirme que celle-ci ne dépend pas du centre dépressionnaire.

b) Il n'y a pas dépendance directe entre le passage de fronts à caractère froid et l'activité microséismique.

c) Il n'y a aucun rapport entre l'activité microséismique et les fronts à caractère chaud.

d) Il n'y a aucune corrélation constante entre la force du vent, la direction du vent et la condition de la mer, d'un côté, et l'activité microséismique, de l'autre.

e) La quasi-totalité de cas examinés a démontré, au contraire, d'une manière absolument évidente que l'activité microséismique dépend directement de la présence, de l'extension et de l'intensité des noyaux de tendance barométrique positive en pleine mer; les quelques cas où cette théorie ne s'est pas révélée absolument certaine, ne peuvent pas être considérés comme une preuve contraire; il est important, en effet, de considérer que même dans les cas douteux, cet élément — voire le noyau de tendance barométrique positive a toujours existé, même s'il ne présentait pas une prévalence nette et évidente vis-à-vis des autres éléments. Bref, cet élément était toujours présent, et seulement dans quelques cas, les observations n'ont pas permis de déterminer une cause plus précise et définie.

Le résultat fondamental de cette recherche est donc le suivant : les microséismes d'origine méditerranéenne sont produits dans les zones en pleine mer touchées par des noyaux de tendance barométrique positive, stationnaires ou en mouvement.

Ce résultat permet de passer à la phase successive de la recherche : ayant déterminé la cause spécifique, il faudra déterminer la cause de son aptitude à produire des microséismes, ainsi que le mécanisme de son action.

Quant à la cause même, elle peut être probablement localisée dans la turbulence de la masse froide et surtout dans les ondulations qui se forment à la surface de discontinuité avec la masse d'air chaud au-dessus; il est raisonnable en effet de supposer que la zone, à une certaine altitude où la substitution des masses produit les effets bariques plus évidents (c'est-à-dire en correspondance des noyaux de tendance positive), soit la même zone où la turbulence est plus active, et les ondulations de la surface frontale sont plus profondes. Quant au mécanisme de l'action, il peut être construit de la manière suivante : le dérangement, la turbulence en altitude et les ondulations de la surface frontale transmettent de l'énergie, à travers les couches atmosphériques, à la surface de la mer sous forme de nombreuses poussées de pression; sous l'action de ces poussées, la mer, selon sa profondeur et son extension, entre en résonance avec des périodes déterminées, et peut ainsi transmettre l'énergie de ses vibrations à la croûte solide de la terre.

Le texte complet de la communication des Prof. Rosini et M. Giorgi est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Dr. Bath : I see that there is no correlation between the centre of cyclones and microseismic activity, this is in agreement with what I found. The correlation with positive barometric tendency is interesting, but the cause must be further investigated.

19. Semaines Internationales pour l'étude de l'agitation microséismique

Le *Dr. Bath* aborde la question des Semaines Internationales pour l'étude des microséismes. Il rappelle que ces périodes avaient été organisées à la suite de la Semaine d'Etudes sur les problèmes des microséismes (Rome, novembre 1951).

En 1952, une Semaine a eu lieu. Il s'agit maintenant de s'entendre sur l'opportunité d'organisation d'autres recherches du même genre.

Une vive discussion s'engage et permet la mise en évidence de deux tendances :

1) *Madame Labrouste* et *M. Rothé* pensent qu'il faudrait fixer a priori des dates, afin que l'on puisse installer des appareils destinés à l'enregistrement des microséismes.

2) MM. *Bath, Bonelli, Carder* et *Hiller,* par contre, estiment qu'il existe une probabilité très faible de rencontrer une période intéressante au point de vue de l'agitation microséismique si l'on fixe a priori les semaines d'études.

Le *Professeur Rothé* estime qu'il est possible de concilier les deux tendances, d'une part en fixant deux périodes d'un mois par an pendant lesquelles les stations qui le désirent peuvent exécuter des enregistrements spéciaux, d'autre part en déterminant a posteriori les périodes intéressantes.

La détermination de ces périodes est confiée à une commission composée de *MM. Bath, Burke-Gaffney, Carder, Hiller* et *Wadati.*

En définitive, les Membres se mettent d'accord sur la résolution ci-dessous :

1) Une commission de l'Association Internationale de Séismologie (MM. Bath, Burke-Gaffney, Carder, Hiller et Wadati) choisit chaque année a posteriori les périodes pour lesquelles les dépouillements sont faits d'heure en heure suivant des règles fixées par le symposium de Rome en 1951.

2) Les stations qui désirent faire des enregistrements spéciaux à grande vitesse et à grande sensibilité sont invitées à choisir de préférence les époques suivantes :

   a) du 15 mars au 15 avril;

   b) du 15 septembre au 15 octobre.

3) Les documents dépouillés sont rassemblés au Bureau Central Séismologique de Strasbourg qui s'efforcera de les publier.

La séance est levée à 11 h. 45.

SEIZIÈME SEANCE

MERCREDI, 22 SEPTEMBRE (après-midi)

Séance commune avec l'Association de Géodésie

Programme

16. — Communications scientifiques : Interprétations gravimétriques et séismiques de la croûte.

89. — *W. D. Lambert :* Report on Earth Tides.

90. — *W. H. Heiskanen :* Report of the Commission N° 15 of International Association of Geodesy for the « Geophysical Interpretation of the Gravity Anomaiies ».

91. — *M. S. Molodensky* and *N. N. Parijsky :* Elastic Tides and Irregularities of the Earth's Rotation in Connection with its Constitution (Density, Elasticity and the Character of the Earth's Rotation).

92. — *A. L. Hales* and *D. I. Gough :* Gravity and Crustal Structure in South Africa.

93. — *C. H. G. Oldham :* Gravity Investigations over Precambrian Rocks in Southeastern Ontario, Canada.

94. — *H. E. Tatel* and *M. A. Tuve :* Seismic Investigation of Crustal Structure.

95. — *T. Akima* and *T. Nagamune:* Dispersion of Seismic Surface Waves and the Structure of Continent and Ocean.

96. — Research Group for Explosion Seismology : Crustal Structure in North-east Japan by Explosion-Seismic Observations.

97. — *J. H. Hodgson :* Direction of Faulting in Pacific Earthquakes.

98. — *Ch. Tsuboi :* Earthquake Epicenters, Volcanoes and Gravity Anomalies in and near Japan.

99. — *R. W. Raitt :* Crustal Structure of the Equatorial Pacific Ocean from Seismic Refraction Observations.

100. — *O. Vecchia :* Map of Middle Terrain Densities down to sea-level in Italy (scale 1 : 10^6).

La séance est ouverte à 14 h. 15 sous la présidence du Professeur Goguel.

16. Communications scientifiques : Interprétations gravimétriques et séismiques de la croûte

89. — Le *Professeur W. D. Lambert* présente et résume un rapport sur les marées terrestres.

Ce rapport sera publié par les soins de l'Association Internationale de Géodésie.

A cette occasion le *Président Goguel* signale que la « European Association of Applied Geophysicists » a assuré l'édition de tables permettant la prévision de la marée terrestre. Ces tables sont calculées avec une précision suffisante pour satisfaire les prospecteurs en tous les lieux du globe.

90. — Le *Professeur Heiskanen* donne lecture du Rapport de la Commission N° 15 de l'Association Internationale de Géodésie : « Geophysical Interpretation of the Gravity Anomalies ».

A. *General Statements.*

1. The gravity anomalies are a useful tool for the studies of the earth's interior.
2. Bouguer gravity anomalies discover qualitatively that the isostatic equilibrium prevails. The Bouguer anomalies are in a way a mirror picture of the topography. The higher the mountains the more negative the Bouguer anomalies are, the deeper the ocean the more positive they are. In large-scale problems they, however, can also mislead in the geophysical interpretations of the gravity anomalies, although they are valuable in the small-scale investigations.
3. How complete the isostatic equilibrium is and how large the deviations from it are can best be studied by the aid of the isostatic gravity anomalies. They discover e. g., that the high mountains and the oceans are up to 85-90 percent in isostatic equilibrium.
4. The isostatic floating theory of Airy seems to be in best agreement with the geophysical facts concerning the earth's interior. This does not exclude the possibility that in some cases the mixture of the floating and the dough hypotheses of Pratt-Hayford is closest to the true state of affairs.
5. The floating equilibrium can be understood either in the local sense (Airy-Heiskanen system) or in regional sense (Vening Meinesz system).
6. The mountain chains and the oceans coasts seem to be in local, the volcanic islands as well as the sedimentation and postglacial uplift areas in regional equilibrium.
7. The Airy isostatic anomalies can be used for determining the thickness of the earth's crust ; the obtained results agree well with the important seismological evidence.
8. Many regions exist which are not in isostatic equilibrium ; most interesting are the strips of negative gravity anomalies, large areas of positive (Europe, eastern part of the Atlantic) or negative isostatic anomalies (large parts of India) and the postglacial uplift areas.
9. The deviations from the equilibrium can be brought about by convection currents, temperature effects, geotectonics, sedimentation, erosion, postglacial uplift of land, strength of the earth's crust (small formations, like the Harz mountain in Germany, are too small to reach the complete equilibrium). On the other hand, the isostatic and Bouguer anomalies of small formations differ from one another so little that it is difficult to decide what type of anomalies fits better.

Gravity measurements to be carried out.

Grace of the interest of the geodetic and geophysical institutions,

military agencies, universities, oil companies and individual scientists of the different countries in the gravity survey of continents and oceans, we now have available several times more gravity stations than before World War II.

We need, however, additional gravity measurements of less surveyed areas, like parts of South America, Africa and particularly gravity measurements at sea, by the Vening Meinesz pendulum (open oceans) and by sub-water gravity meters (shallow shalves).

An accuracy of 1 mgal of the gravity measurements, if the measuring errors are not systematical. is sufficient and even the accuracy of 3 mgal is useful, because the error brought about by the different reductions can be of the order of some mgals.

It is very important to continue the tying of the gravity base stations of the world to the same gravity system. This world-wide connection, carried out particularly by the Wisconsin University (Woollard) group is of significance also for the geophysical application, and without such connection, the gravimetrical computation of the undulations of the geoid and the deflection of the vertical would be impossible.

Problems to be studied.

1. To carry out the topographic-isostatic reduction of the gravity anomalies according to different isostatic assumptions. The terrain correction (Geländereduktion) should be estimated in the country where the measurements have been done, because it presumes good and big scale maps. The cartographic method would be preferable in the isostatic reduction. The Isostatic Institute of the IAG at Helsinki and the Bataafsche Petroleum Company at the Hague have done important work in preparing and publishing isostatic reduction maps which give the whole isostatic reduction of large areas. The topographic isostatic reduction maps of the Isostatic Institute give the sum of topographic and isostatic reduction of the Hayford zones 10 to 1 for the whole world (according to several assumptions).

Still more important might be the universal reduction method (the mass line method) developed at the Mapping and Charting Research Laboratory of the Ohio State University. This method needs only the mean elevations or depths of the good-sized spherical trapezoids all over the world. The high-speed computing machines can then compute the entire isostatic reduction at any needed points.

Every country can contribute much to these computations in reading the mean elevations or depths of these squares of its own territory.

2. To study the isostatic equilibrium as well as the cause of the deviation from it at all such areas from which adequate gravity material and topographic maps exist. Every mountain, valley, ocean coast, or island behaves in this respect in different ways. Any sweeping conclusions suitable for details of different cases do not exist.
3. To continue the study of the Island arc areas.
4. To study the phenomena which bring about the large areas of one sign gravity anomaly.

Some remarks.

The gravimetrists have to consider and also will consider in their computations the increasing knowledge of the crustal mechanical

properties and the new findings of the seismologists. The gravity data give good values for the mean depth of the disturbing masses. We have to study how much this mean depth will vary in different parts of the world. Such studies we can start, either keeping the level of zero elevation as the normal surface, as has been the case until now, or else to begin from the ocean bottom — the oceans comprise 2/3 of the earth's surface as H. Hess has suggested.

The gravity data allow also the computation of the undulations of the geoid and deflections of the vertical, and in this way can convert the existing geodetic systems of different countries to a World geodetic system. The undulation maps and the deflection of the vertical maps are important also from the geophysical point of view, as they help to localize the disturbing masses.

Professor Vening-Meinesz mentions that in addition to the excellent and stimulating report of Prof. Heiskanen there are two ways of interpreting gravity anomalies. First there is the usual interpretation by determining the situation of the anomalous masses causing the gravity anomalies. It is well known that these interpretations are liable to doubt as the problem does not allow a unique solution.

In the second place one can say that if there is a patch of anomalies of the same sign of a horizontal dimension equalling or exceeding the wave-length of the rigid crust, there must be forces working in the crust which disturb its isostatic equilibrium, or that they must have worked in a so recent period that the deviation of equilibrium has not yet had the time to disappear. This means that the disturbing forces must have worked until a time not longer ago than a few times 10.000 years. This interpretation has a more certain base than the usual interpretation first mentioned.

91. — Le *Professeur Molodensky* présente la communication intitulée : Elastic Tides and Irregularities of the Earth's Rotation in Connection with its Constitution *by M. S. Molodensky* and *N. N. Parijsky.*

For several Earth models the deformations which appear under the influence of elastic bodily tides have been computed. In all the models the sphere is taken to be elastic, compressible, gravitating, of heterogeneous density and of variable elasticity characteristics. Moreover, the seismic waves velocities are close to those observed in the Earth mantle. The density distribution and the rigidity vary from model to model. An estimation is made of the influence of the compressibility and heterogeneity of the Earth's core, of changes in the ellipticity of the Earth and of the position of the boundary of the core. From the observed period of free nutation two different conjectures can be made :

1. the rigidity μ in the core is close to $0{,}6.10^{12}$ dyn/cm^2;

2. in the core $\mu = 0$, and its moment of inertia is no less than 10 per cent of the moment of inertia of the Earth.

Molodensky has worked out his own method for solving the problem of small elastic deformations of the Earth in response to perturbations expressed by spherical functions of any order, on the

assumption that the Earth is of heterogeneous density and has variable elastic characteristics. This method enables to solve the question of the influence of recrystallization or phase transformations in the Earth's body on the angular velocity of its rotation and on the gravity at its surface.

Cases where recrystallization of matter occurred in a thin layer at different distances from the Earth's centre have been considered. This recrystallization is accompanied by slight changes of the density.

The whole of the Earth's body is elastically deformed and its moment of inertia, its angular velocity and gravity at the surface undergo certain changes too. The observed changes of the angular velocity of the Earth can be explained by density variations of about 0.1 gr/cm^3 within a 10 m layer. For deformations expressed by spherical functions of higher order observable changes in the gravity at the surface are possible.

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Prof. Tomascheck observed that a change of the rotational speed of the Earth of about 0.001 sec. occurred during spring of this year. By chance observations of tilt and gravity with horizontal pendulums and gravimeters were going on at this time in England. No perceptible change in tilt or gravity could be detected around the critical time. It would be interesting to know if observations in Japan show an influence.

D. Cook : Is the secular variation of gravity that Prof. Mihailov is examining that of the difference of gravity between two stations or of the absolute value at a single station ?

It was answered that it was at a single station.

92. — Le *Professeur Hales* présente sa communication intitulée : Gravity and Crustal Structure in South Africa.

Gravimeter observations made in the Union of South Africa under the direction of Dr. J. F. Enslin of the Geological Survey have been reduced isostatically on five hypotheses with regard to the distribution of the compensation. A preliminary investigation has been made of the correlation of the anomalies with height.

A provisional picture of the general state of compensation of the sub-continent is given and some of the departures from local compensation are discussed.

Dr. Cook : Is the flat minimum of means of squares of isostatic anomalies against elevation in part due to the fact that the same distribution of gravity at the surface may be produced by mass distribution at different depths ?

Prof. Hales : This is part of the cause, the fact that other sources of anomaly are present also obscures the minimum.

Prof. Birch : You obtain a flat minimum, because you are in a flat country.

Le *Président Goguel* demande quelles sont les altitudes extrêmes.

Prof. Hales answered that the altitudes vary from 6,000 feet to zero, but over some regions it varies slightly.

93. — La communication de *M. C. H. G. Oldham* intitulée : Investigations relatives à la gravité, faites sur des roches précambriennes du Sud-Est de l'Ontario est présentée par le Prof. *J. Tuzo Wilson.*

Des diplômés de l'Université de Toronto, à l'aide de gravimètres North American et Worden, étalonnés par eux, ont mesuré la gravité en 1,600 endroits de la partie sud-est de l'Ontario, sur 75,000 milles carrés d'une superficie située dans la subdivision Grenville du bouclier canadien. Ils ont calculé les anomalies de Bouguer et mesuré la densité de 1,300 échantillons de roche recueillis.

Ils se sont servis du calculateur à touche Ferranti dit Ferut, installé à l'Université de Toronto, pour analyser les données et calculer l'action « régionale » de la gravité. Ils ont employé la méthode des moindres carrés, à polynômes orthogonaux. C'est la première fois, croit-on, qu'on utilise cette méthode de calculer « l'action régionale » en matière de données sur la gravité.

Pour faciliter la lecture de la carte de gravité, divers travaux viennent d'être effectués à Toronto : détermination d'âges, mesures de radioactivité, interprétation de photographies aériennes et préparation d'un recueil des cartes géologiques et aéromagnétiques publiées.

On peut établir une corrélation entre la plupart des anomalies de moindre importance, d'une part, et les densités mesurées de roches et la géologie connue, d'autre part, mais on ne peut le faire dans le cas d'une importante anomalie Bouguer, négative et régionale, qui, d'après les explications données, représente les racines peu épaisses d'une ancienne chaîne montagneuse.

A paper dealing with the more mathematical aspects of this communication entitled « Orthogonal Polynomials : Their Use in estimating the Regional Effect by C. H. G. Oldham and D. B. Sutherland, has been accepted for publication in « *Geophysics* », 8 figs.

Prof. Heiskanen asked if there were differences in elevation.

Prof. Wilson replied that the differences were not large, negative anomalies run at right angles to troughs.

Prof. Vening-Meinesz asked whether isostatic reduction would not have given a better view than the splitting up the gravity anomalies in a regional and a local part without a physical background.

Prof. Wilson said that they believe that there is a change at 35 km and that this region is not in equilibrium.

Dr. Hodgson added that Dr. Oldham's work and his had a correlation which is closer than suggested.

Le *Président Goguel* demande si un simple calcul de valeur moyenne, par intégration dans un cercle de rayon convenable, n'aurait pas fourni aussi bien l'anomalie régionale cherchée.

94. — La communication de *MM. H. E. Tatel* et *M. A. Tuve* intitulée : « Seismic Investigation of Crustal Structure » est présentée par le *Dr. Harry W. Wells,* Carnegie Institution of Washington.

Since their last report the authors have endeavored to determine in more detail the precise velocity versus depth relationship in a typical continental region. They have found that the seismic method as now used gives at best only certain limits on the velocity versus depth, and that from the usual observations a unique « crustal structure » may not be obtained.

The authors have been thoroughly disillusioned in their search for valid evidence for granitic or basaltic « layers ». They are satisfied that most of the « phases » interpreted by various workers as evidence for such « layers » are due to interference effects of superposed waves. Since these « phases » shift considerably in their arrival times and amplitudes when the shot point or the receivers are moved a few thousand feet or less, the different records indicate greatly different depths for the assumed « layers » over identically the same path (10 to 80 miles) from shot groups to receivers. It is not possible to remain convinced of hypothetical horizontal « layers » under such circumstances for those regions where they have observed. Earthquakes have not provided a test of a suitably analytical character on this point.

The various models for velocity versus depth which are compatible with their data show at most a slow increase from 6 km/sec. compressional velocity to about 6-1/2 km/sec. at three quarters the crustal depth. As the depth is further increased to the outer mantle rock (8 km/sec.) many possibilities exist which may explain the data. For example, as depth is increased beyond the 6-1/2 km/sec. region, the velocity may increase slowly for several kilometers and then abruptly to 8 km/sec. within a final zone or thickness of less than several tens of meters. On the other hand, it may increase more and more rapidly throughout a deeply buried transition zone of several kilometers thickness until the velocity is 8 km/sec. In any event, most of the increase is localized within the deepest three or four km of the crust near the mantle rocks (8 km/sec.). There is no evidence which might point to a deeply buried « low velocity layer ».

Much of their work has been concerned with the nature of the continuous ground motion after the first arrival. While they can not at the present make complete generalizations, separate experiments have shown that the earth's surface probably plays a predominant role in these motions : (1) A deep shot showed the waves after the Rayleigh wave to be greatly diminished. (2) Motion meters using strain gauges (after Benioff) showed Rayleigh wave motion after the arrival of the P but before arrival of the shear waves. (On the other hand, several records in other locations showed motions too complex to analyze.) (3) A model experiment has shown the classical Lamb type seismograms to be confused greatly by making indentations in the surface of the order of one wave length in size between source and receiver. (4) Multiple seismograms show continued radiation from the source after the arrival of the P wave (and before the

S wave), which may be accounted for by slow surface waves generated at successive radial distances by the initial P waves. Subsurface tests are in progress.

The content of the paper by MM. Tatel and Tuve « Seismic Investigations of crustal structure » has been published under several different titles listed accordingly : Tatel (H. E.), Adams (L. H.) and Tuve (M. A.), Studies of the earth's crust using waves from explosions, *Proceedings of the American Philos. Soc.*, Vol. 97, N° 6, Dec. 16, 1953, pp. 658-669, 16 figs.; Tatel (H. E.), Howard (E.), Merle (A.) and Tuve (M.A.), Note on the nature of a seismogram I, II, *Journal of Geophysical Research,* Vol. 59, N° 2, June, 1954, pp. 287-294; Tuve (M. A.), Howard (E.), Tatel (H. E.) and Pembroke (J. Hart.), Crustal structure from seismic exploration, *Journal of Geophysical Research,* Vol. 59, N° 3, Sept. 1954, pp. 415-422, 3 figs.

Prof. Gutenberg : Excellent reflection data has been obtained by European and Californian seismologists and do not agree with the conclusions reported by Tatel and Tuve. Many types of observations reported during the present meeting have been interpreted by their observers as indicating low-velocity layers. There is excellent agreement between conclusions drawn from earthquake waves and those from explosion waves.

95. — Le *Prof. Wadati* présente la communication de MM. *T. S. Akima* et *T. Nagamune* intitulée : Dispersion of Seismic Surface Waves and the Structure of Continent and Ocean.

Many authors have estimated the crustal structure of various regions by observations of dispersions either of Love or Rayleigh waves. But as it is clear by Y. Sato's study, the crustal structure cannot be estimated by the dispersion curve of either Love or Rayleigh waves only.

Our estimations were performed by observations of both Love and Rayleigh wave dispersions.

To some seismograms containing many short period waves which make difficult to observe long period surface waves clearly, the torsion pendulum low-pass filter which one of the present authors had constructed for this purpose was used.

The contents of this paper may be concluded as follows :

1. Crustal structures estimated only from dispersion of Love waves cannot often satisfy the dispersion of Rayleigh waves.

2. Torsion pendulum low-pass filter is quite powerful for observational study of surface waves especially when original seismograms to be analysed contain short period waves.

3. Dispersion of seismic surface waves, especially that of Rayleigh waves, is quite sensitive to the crustal structure.

4. The difference of oceanic paths to Japan through the central and through the western Pacific have much influence upon the dispersion of Rayleigh waves but have nearly none upon that of Love waves.

Le texte complet de la communication de T. S. Akima et T. Nagamune est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Le *Prof. Rothé* remarque avec intérêt la distinction faite par les auteurs entre les régions appelées par eux C et D et qui sont séparées par la Cordillère des Iles Bonin et de l'île de Guam. Cette ligne sépare le domaine du véritable Océan Pacifique du Bassin des Philippines à allure continentale.

96. — Le *Prof. Wadati* présente la communication intitulée : « Crustal Structure in North-East Japan by Explosion-Seismic Observations » by the Research Group for Explosion Seismology (R.G.E.S.).

Since 1950, R.G.E.S. has made explosion-seismological observations for five times in the north-eastern part of Japan. Dates and outlines of these observations are listed below :

Date	*Shot point*	*Amount of explosives*	*Observation point*
Oct. 25, 1950	Isibuti, Iwate Pref.	57 ton	8
Dec. 27, 1951	» »	7,8 ton	16
Jul. 25, 1952	» »	5.5 ton	19
Dec. 7, 1952	» »	30 ton	19
Sep. 13, 1953	» »	42 ton	15

Reports have been published separately. However, some contradictions have been found among them, because interpretations were made independently in each time on an assumption of horizontal layering. Here, the general interpretation of the five experiments will be presented, in which the most probable structure of the earth's crust in north-east Japan is figured out.

An assumption of horizontal layering, employed so far, can no more cover our observation results when the whole data are taken into consideration. For discrepancies between theoretical values based upon the above assumption and observation values sometimes exceed one second which is far greater than our accuracy.

After many trial computations, the following interpretation of the earth's crust will be presented.

(1) Near the Isibuti shot-point, a surface layer of 2.51 km/sec. is found (P_1 layer). In the east-west cross section, this P_1 layer declines eastward with a dip angle of 9° and thins sharply at a point 14 km east of Isibuti. Its depth is 500 m at the Isibuti shot-point.

(2) West of Isibuti, a surface layer can be also found, and unfortunately no data are available to determine a velocity of this layer. However, if this layer is of the same type of the P_1 layer (highly probable from the viewpoint of geology), its depth is approximately 1 km.

(3) The surface layer described in (2) is very thin or interrupted near the backbone mountains.

(4) East of the fault where P_1 layer thins sharply, the surface layer is still present with a depth of 300 m near Mizusawa. However, near the Kamaisi shot-point, no P_1 layer can be seen.

(5) Below P_1 layer, P_2 layer of 5.7—5.8 km/sec. is found and rises to the surface of the ground in Kitakami mountains. The strike of this layer is N 20-30 E and declines westward with a dip angle of 6—10°.

(6) P_2 layer is underlaid by P_3 layer of 6.1—6.25 km/sec. The depth of the boundary between P_2 and P_3 layers is probably 500—2.000 m near Kamaisi shot-point.

(7) P_3 layer is again underlaid by the 4th layer (P_4). If horizontally underlaid, its apparent velocity is 7.5—8.0 km/sec. and its thickness is 20—25 km if its lower boundary is also horizontal. Naturally the boundary between P_3 and P_4 will not be horizontal, but accuracies in upper layers are not high enough to discuss this problem.

(8) Velocities, strikes, dips and thicknesses in P_2 and P_3 layers are dependent of each other. If one of these parameters can be determined in higher accuracy, the present ambiguity of other parameters will be much lowered. Values in this report show the greatest allowance.

(9) The interpretations presented here and derived only from the series of experiments are well acceptable from the viewpoints of gravity and surface geology.

(10) Recently, a 6th experiment of rather small scale was made to confirm our interpretation, and results were very beautiful.

Le texte complet de cette communication est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Le *Prof. Rothé* mentionne qu'en France les travaux récents ont montré l'existence d'une couche à vitesse 6,0 km/sec. aussi bien dans le Languedoc que dans le Bassin Parisien.

Prof. Bullen : New Zealand crustal structure is very similar to that of Japan. This is perhaps not surprising because of the similarity of their locations near the Pacific perimeter. The results of explosion seismology in New Zealand along a profile about 120 miles long and containing approximately 40 stations are as follows :

V_1 3,5 V_2 5,5 V_3 6,0 V_4 6,3 V_5 8,1 km/sec., corresponding thicknesses ($\frac{1}{2}$, $1\frac{1}{2}$, 7 and 9 km) giving total crustal thicknesses of about 18 km.

Does Dr. Wadati find the same difficulty as Drs. Tatel and Tuve found in identifying the arrivals before P_n in seismograms obtained on *arrays of geophones* (such as T-arrays) used instead of single detectors ?

Dr. Wadati : We found a difficulty but many different people interpreted the seismograms and gave agreement.

97. — Le *Dr. J. H. Hodgson* présente sa communication intitulée : Direction des dislocations dans les séismes de l'Océan Pacifique.

Depuis déjà plusieurs années, l'Observatoire fédéral (du Canada) emploie la méthode Byerly pour étudier la direction des dislocations

causées par les tremblements de terre, et 34 séismes en tout ont été analysés jusqu'à présent. Pour ce qui est de tous ces tremblements de terre, sauf 3, la solution s'appuie sur des données fournies par des investigateurs de séismes, qui ont collaboré en répondant à des questionnaires.

La première conclusion tirée du travail accompli jusqu'à ce jour, est que la faille transversale a joué un rôle plus important dans l'évolution tectonique qu'on ne lui en attribue normalement. En ce qui concerne 11 tremblements de terre survenus dans le sud de l'Océan Pacifique, un au Japon et 6 aux îles Kouriles qui ont été analysés, tous démontrent une dislocation transversale pour des profondeurs de centre variant de moins que la normale jusqu'à 550 km. Dans les Aléoutiennes, 2 des 3 séismes analysés, et, dans l'Amérique du Sud, 4 des 5, résultaient de failles transversales. Le centre d'un des tremblements de terre en Amérique du Sud se trouvait à 600 km. de profondeur. Dans la région partant de l'Alaska et longeant le littoral de la Colombie-Britannique jusqu'à Seattle, un seul des 6 séismes prédominait par la dislocation transversale, quatre résultaient de failles normales et un de pli-faille inverse. Dans l'Indou-Kouch, 2 analyses ont indiqué des failles normales. Ces résultats permettent de croire à une différence fondamentale entre les arcs d'îles et les étendues continentales.

Une seule des failles ci-devant indiquées était purement transversale, chacune des autres accusant un certain déplacement dans la direction du pendage. Suivant que ce déplacement du pendage est inverse ou normal, on peut supposer que les forces tectoniques sont attribuables à la compression ou à la tension. Une fois analysés, soit par étendues individuelles ou dans l'ensemble, ces résultats n'indiquent pas clairement des variations systématiques de compression et de tension en profondeur. Dans la profondeur ne dépassant pas 550 km, les 2 séismes étudiés indiquent des forces de compression. Pour les profondeurs variant de 150 km à 350 km, 4 des séismes indiquent des tensions et un, la compression. A 100 km, un des tremblements de terre révèle la tension, 4 la compression, tandis qu'aux foyers normaux, 8 montrent la tension et 13 la compression.

Il ne faut pas prendre ces résultats comme définitifs. Dans les cas où la faille est surtout transversale, la direction en ce qui a trait au déplacement du pendage peut être purement accidentelle. On aborderait le problème plus objectivement en déterminant, dans chacun des cas, le régime d'effort qui cause le dérangement horizontal observé. Ceci suppose une certaine théorie de la mécanique des dérangements, et aucune théorie formulée jusqu'à présent ne semble suffisante pour expliquer des dérangements à des profondeurs variant de 30 à 600 km.

98. — Le *Prof. Ch. Tsuboi* présente sa communication intitulée : Earthquake Epicentres, Volcanoes and Gravity Anomalies in and near Japan.

« Maps showing the distributions of gravity anomalies, earthquake epicentres and of Quaternary volcanoes in Japan are presented in order to provide materials for discussions regarding the mutual relation existing among them in general.

Gravity anomalies have been determined at about 5000 points throughout the country. The epicentres of earthquakes plotted on the map are approximately 3000 in number and they are indicated by circles of different radii according to magnitudes. These plots are based on the observations 1900-1950 made by the seismological net works belonging to the Central Meteorological Observatory.

Notable facts to be seen on the maps are briefly sketched. »

Le texte complet de la communication du Prof. Tsuboi est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Prof. Heiskanen : I congratulate Prof. Tsuboi on this very important work. Strongly positive anomalies to the North and negative to the South even after reduction makes this a very interesting study.

Prof. Vening-Meinesz congratulates Prof. Tsuboi with the enormous work done which is so very important for the study of the tectonic of island arcs and would like to see a comparative study with the fields of Indonesia and the Caribbean.

99. — *Prof. Russell W. Raitt* reads his paper : Crustal Structure of the Equatorial Pacific Ocean from Seismic Refraction Observations.

« Seismic refraction studies have been made at forty-two localities in the Pacific Ocean west of the American continental slope, between latitudes 21° S and 32° N and longitudes 161° E and 112° W. At thirty-one of these localities penetration to the mantle, indicated by a velocity greater than 8 km/sec, was achieved.

The depth to the mantle varies between 10 and 20 km below sea level. For a typical deep sea station of 5 km sea depth it is 11 km below sea level. Velocities of the crust above the mantle vary between $6\frac{1}{2}$ and 7 km/sec. Mantle velocities vary between 8.0 and 8.6 km/sec. Although some of this variation may represent interpretation error rather than variation of formation velocity, it is probable that there is lateral variability of the material of the crust and the upper mantle. Additional support for this conclusion is found in the poor correlation between sea depth and crustal thickness. »

100. — Le *Prof. O. Vecchia* présente sa communication intitulée : Map of Middle Terrain Densities down to sea level in Italy (scale $1 : 10^6$).

The author presents a map of Italy, at a scale of one millimeter to a kilometer, representing middle terrain densities from the surface to sea level; it may be utilized to calculate gravity reductions — Bouguer and land corrections — both for geodetic and exploration geologic uses. The new pattern differs considerably from conventional surface geologic maps, which are chronologic or sometimes lithologic. Parts of neighbouring States were introduced in the map for land corrections only and are therefore rather approximative.

Densities are divided in intervals of 0,2 and were calculated on the basis of local stratigraphy and tectonics, as they may be derived from existing profiles, maps and special papers.

Estimating rock densities becomes particularly uncertain when one has to deal with geologic formations consisting of detrital matter, volcanics of other variably compound terrains, which are just the formations making up most of Italy. Many doubts are also caused by insufficient knowledge of underground tectonics and density variation with depth of burial. As a whole, however, all these causes of errors were not so heavy as one feared from the beginning.

In spite of the imprecisions originated by the aforesaid causes, the use of this map in gravity corrections has made possible to eliminate errors of 10, 20 or up to 30 mgal, found in Highland measures reduced with preceding methods. In low altitude areas the map is probably more erroneous but in such cases the gravity corrections are much smaller.

La séance est levée à 18 h. 30 m.

DIX-SEPTIÈME SÉANCE

JEUDI, 23 SEPTEMBRE (matin)

Programme

16. — Communications scientifiques : Géographie séismologique.

101. — *E. F. Savarensky :* Seismic Survey and analysis of seismic observations in the USSR.

102. — *E. Trapp :* New Possibilities of the practical Realization of Macroseismic Dates.

103. — *K. Wadati* and *Y. Iwai :* Minute Investigations on the Seismicity in Japan.

104. — *S. K. Pramanik* and *S. M. Mukherjee :* The Assam Earthquake of August 15, 1950.

105. — *N. Shalem :* Séismicité et les cassures érythréennes dans l'Hinterland de la vallée du Jourdain.

106. — *H. Sassa* and *E. Nishimura :* On Phenomena Forerunning Earthquakes.

107. — *E. Peterschmitt :* La Constitution physique de l'écorce terrestre en Europe occidentale.

108. — *H. Dilgan* et *T. Hagiwara :* Rapport sur le tremblement de terre de Yenidje, le 18 mars 1953.

109. — *N. Pinar :* The Earthquake of Yenice - Gönen, Northwestern Turkey, March 18, 1953.

110. — *J. Debrach :* Sur quelques alignements séismiques remarquables du Maroc. Essai d'interprétation tectonique.

111. — *M. De Panfilis :* Rilevamenti macrosismici per il territorio italiano dal 1930 al 1952.

112. — *D. Di Filippo, L. Marcelli :* « Etude sur le tremblement de terre de Céphalonie (du 12 août 1953), en considérant tout particulièrement la nature physique de la secousse à son épicentre ».

La séance est ouverte à 9 h. 10 m. par le *Prof. Gutenberg,* qui confie la présidence au *Prof. Caloi.*

16. Communications scientifiques : Géographie séismologique

101. — La communication de M. *E. F. Savarensky* intitulée : Seismic Survey and Analysis of seismic Observations in the USSR est présentée par le *Prof. Dr. G. P. Gorshkov.*

« The Study of earthquakes was first undertaken in Russia in the late nineteenth century by Prof. I. V. Mushketov and A. P. Orlov and was mainly devoted to problems of seismogeology.

Systematic observations with special instruments were started by the Permanent Central Seismic Commission under B. B. Galitzyn who in 1902 was the first to apply the galvanometric method of recording. In 1906 seismographs designed by Galitzyn were introduced at some Russian seismographic stations and in 1910-1911 they made their appearance at foreign stations. B. B. Galitzyn created a network of seismographic stations in Russia. It consisted of first-class stations (equipped with galvanometric record instruments) and second-class stations (with mechanical record instruments). Moreover, B. B. Galitzyn developed a method of locating the epicentre from the data of a single station (1909), investigated the internal constitution of the Earth, making use of the angle of emergence of seismic rays (1915) and studied many other problems of seismology.

In 1927-1930 industrial development in the regions of seismic activities in the USSR brought into being a network of the so-called regional stations. These were headed by Prof. P. M. Nikiforov and were equipped with seismographs of his design.

At the outbreak of World War II 32 seismograph stations were in operation in the USSR. A general map of regional distribution of seismic activity on the territory of the USSR was compiled; measures for earthquake-proof construction were planned; the constitution of the earth's crust in Central Asia was determined. Considerable success was achieved in the development of the theory of propagation of elastic waves (contributions of S. L. Sobolev and V. I. Smirnov).

After the Ashkhabad earthquake of 1948 special attention was paid to the problem of earthquake prediction. Accordingly the network of seismographic stations on the territory of the USSR has been widened. By now 70 stations are in operation, all of them equipped with new types of galvanometric record seismograph. These stations supply helpful information for the solution of various seismological problems. They are, moreover, provided with special photoelectric equipment, which controls the brightness of the record and the magnification of the instruments when the amplitude of oscillation is large enough. Some of the stations, located in regions of seismic activity are also equipped with special seismographs for recording major earthquakes. In the whole network the equipment of the stations and the method of interpretation conform to a certain standard. The results of the seismic observations are published in the form of quarterly bulletins.

For the investigation of the conditions and causes of earthquakes maps of seismicity are very useful, which show the exact location of epicentres and indicate the earthquake energy. Therefore

the Geophysical Institute of the Academy of Sciences of the USRR is by now concerned with the development of a method for mass determinations of earthquake intensity and for a rigorous location of the focus. Soviet seismologists are compiling at present regionai USSR maps of seismicity where particular attention is given accuracy of date on earthquake intensity and the location of the focus.

A method for the determination of the nature of the displacements occurring in the focus has been developed at the Geophysical Institute by V. J. Kailis-Borok. This method is based on the amplitudes of the arriving longitudinal and transverse waves and should be considered a remarkable achievement in the study of the earthquake mechanism.

As regards the use of seismic observations in the study of the internal constitution of the earth, the following contributions made lately in the USSR may be mentioned here :

A. A. Treskov has developed a new method for the determination of the thickness of the earth's crust, based on the difference of arrival times of reflections from the surface of the earth and from the bottom of the earth's crust.

The author has worked out a method for the investigation of the velocity-depth function, based on observations of the angle of emergence of the seismic rays. He showed that heterogeneity in the uppermost layers of the earth cannot essentially influence this method when waves of sufficient lengths are observed.

The constitution of the earth's core has also been investigated in the USSR. In these investigations the presence of waves reflected from the inner core has been proved. »

Les mémoires suivants présentés par la Délégation russe à l'Assemblée de Rome seront insérés dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19 :

Gamburzev (G. A.), On some new methods of seismological research.

Kailis-Borok (V. I.) : Methods and Results of the Investigation of Earthquake Mechanism (a brief information).

Kirnos (D. P.) and Kharin (D. A.), Basic equipment of seismological stations in the U.S.S.R.

Prof. Gutenberg calls on cooperation of all countries for seismology.

Dr. Bath : How does the Russian Academy of Sciences make energy computation ?

Prof. Gorshkov : By using the Mercalli-Cancani scale and by a new method, for instance, by constructing a device which permits the elaboration.

Dr. Fr. Press : Has a surface faulting in the great Kamchatka shock been found ?

Prof. Gorshkov : The epicentre was 200 km offshore, the shock was weak on land, there were probably changes at the sea bottom and there was a tsunami.

Prof. Benioff : Were there many deaths ?

Prof. Gorshkov : rather.

Dr. Wadati : How high was the tsunami ?

Prof. Gorshkov : A few meters.

Dr. Carder : Were the deaths as a result of the tsunami ?

Prof. Gorshkov : Yes.

102. — La communication du *Dr. Trapp* intitulée : « New Possibilities of the practical Realization of Macroseismic Dates» est présentée par *M. Peterschmitt.*

To represent practically the earthquake activity in a country during a greater period, we shall try to expose in as plain and distinctive way as possible the individual earthquake event. It appears that the introduction of the two terms « seismic efficiency » and « summary isoseiste » is very advantageous.

I.

The effects of a seism on the surface of the earth are closely connected with the intensity and the extension shown. We derive the « seismic efficiency » from these two quantities as an indefinite number, especially fit for statistic or graphic realization.

In a study of the seismicity of the Western Alps. J. P. Rothé has shown, in 1941, how to represent suitably each earthquake macroseismically comprehended, by a characteristic figure as follows:

$$K = R/J$$

J....epicentral intensity
R....macroseismic radius

When studying the Austrian earthquakes in 1950, M. Toperczer and E. Trapp similarly worked out such figures by formation of products. In 1953, the former created the term « seismic efficiency »

$$w = J.f$$

f ....macroseismic surface in km²
w....« seismische Wirksamkeit »

and in 1954, the latter proposed the formula

$$w = J.10g_{10}f,$$

in order to receive more profitable figures. Therefore f need not be known more exactly than the use of logarithms of one tenth requires.

To be able to judge the usefulness of the efficiency-figures, we are to know which values they can possibly take (see simple examples in table I). The greater efficiency corresponds to the greater w-figure, whereas however once the macroseismic surface, once the epicentral intensity dominates. How far the figures can be ambiguous, we see from table 2 (improbable cases are in brackets). This ambiguity, however, is

table I

J	f	log f	w
3°	10 km²	1	3
4	100	2	8
4	1000	3	12
5	10000	4	20
6	1000	3	18
7	100000	5	35
10	1000000	6	60

table II

J	f	log f	w
(4°	1000000 km²	6	24)
5	63000	4,8	24
5,5	23000	4,36	24
6	10000	4	24
6,5	4900	3,69	24
(7	2700	3,43	24)
(8	1000	3	24)

insignificant in the statistic work which essentially consists of the summation of w-figures.

II.

As far as we have charts of isoseistes of several earthquakes occurred in the same region, we can very easily summarize them graphically by means of the « summary isoseistes ». We simply join all the planes that are surrounded by the same isoseiste to one area by drawing a collective « summary isoseiste ». In other words the whole area shaken during a given epoch once or several times by equal intensity, is plotted. To distinguish these from the ordinary isoseistes (e.g. : 4°, 5°, 6°), the corresponding summary isoseistes get a dash above the number ($\bar{4}°$, $\bar{5}°$, $\bar{6}°$,)

The use of the summary isoseistes is very favourable to the demonstration of those parts of a country that are threatened by earthquakes : The $\bar{6}°$ - isoseiste encircles all the damaged zones, and the trace of the $\bar{5}°$ - isoseiste virtually indicates the limit of the perilous seismicity.

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Dr. Bath : Why do you combine the intensities in such an arbitrary method ? Wouldn't it be better to combine them in a way that would give a number proportional to energy ?

Dr. Toperczer : Le produit est probablement proportionnel à l'énergie.

Le *Dr. Bath* pense que la question est sans doute plus compliquée.

Dr. De Panfilis : Si j'ai bien compris, selon la définition donnée par Mr. Trapp, une « Summary isoséiste », c'est-à-dire une « isoséiste-somme », délimite sur la carte géographique la zone qui, pendant une période de temps, a été secouée avec une certaine intensité, par exemple, avec l'intensité du VI^e^ degré, si l'« isoséiste-somme » considérée est du 6^e^ degré. Cette zone contiendra en général des parties qui, dans la période de temps considérée, ont été secouées une fois seulement, tandis que d'autres auront été secouées deux fois et d'autres encore davantage. Cette fréquence de secousses, qui varie dans les diverses zones contenues à l'intérieur d'une même « isoséiste-somme » ne se trouve néanmoins pas indiquée. On a donc, par rapport à la séismicité de la zone considérée, une représentation qui met

en lumière les intensités maxima et non pas les fréquences des tremblements de terre qui se sont produits dans cette zone.

Mais il est évident que, pour représenter la séismicité d'une zone d'une manière adéquate pour les travaux de bâtiments et pour l'assurance de propriétés contre les dommages séismiques, il est essentiel de tenir compte non seulement de l'intensité mais aussi de la fréquence. Une Société d'Assurance ne demanderait certainement pas le même tarif pour assurer deux édifices identiques par leur construction, mais situés l'un dans une zone où, pendant une certaine période, une seule secousse s'est manifestée — par exemple de VII^{e} degré — et l'autre dans une zone où, dans la même période, plusieurs secousses de VII^{e} degré se sont produites.

On pourrait se servir de hachures diverses pour différencier dans une zone limitée par une même « isoséiste-somme », les parties caractérisées par des fréquences diverses. Mais, de cette manière même, la représentation ne serait pas complète, car, dans la zone limitée par l'« isoséiste-somme » d'un certain degré, il n'y aurait aucune indication des secousses de degré inférieur qui s'y sont produites.

Je pense donc que, pour établir la façon la plus complète et la plus simple, la manière dont se comporte au point de vue séismique une zone donnée pendant une certaine période de temps, il est nécessaire et suffisant d'avoir à sa disposition les cartes contenant les isoséistes de tous les tremblements de terre qui s'y sont produits dans cette période. D'après l'examen de ces cartes il sera facile de connaître pour chaque localité le nombre de tremblements et leur intensité.

Toute sommation ne peut, je pense, que cacher quelques-uns des éléments fondamentaux de la séismicité, qu'il serait, au contraire, nécessaire de mettre en parfaite évidence.

103. — La communication intitulée : « Investigation minutieuse de la séismicité au Japon, par *K. Wadati* et *Y. Iwai* » est présentée par le *Dr. Wadati.*

Les auteurs ont dessiné des cartes montrant la structure fine de la séismicité au Japon et dans son voisinage, zone qui est connue comme une des régions du monde où les tremblements de terre sont les plus fréquents. Pour tous les séismes avec des magnitudes plus grandes que 5, qui se sont produits pendant la période 1926-1953, on a obtenu la distribution précise dans l'espace de leurs hypocentres. Même dans cette étude régionale détaillée on peut remarquer le fait que les profondeurs focales deviennent de plus en plus grandes à partir de la fosse océanique et au fur et à mesure qu'on atteint la plate-forme continentale, la terre et enfin la zone volcanique. Il est très intéressant de noter qu'au Japon la région où actuellement les volcans sont en intense activité est fréquemment ébranlée par des séismes intermédiaires alors qu'au contraire on ne connaît pratiquement aucun séisme intermédiaire dans les régions sans volcans actifs. Il est généralement admis qu'il n'existe aucune relation entre l'occurrence des séismes intermédiaires et l'activité volcanique actuelle. Mais, autant que le montre cette investigation, la coïncidence susmentionnée semble trop remarquable pour être considérée comme étant accidentelle.

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Dr. Bath : The map is very useful especially for focal depths. What is the average depth accuracy of depth between 0-100 km ?

Dr. Wadati : It is depending on the position of the epicentre, between 10 and 50 km.

Dr. Carder : Will the new map separate deep and shallow shocks ?

Dr. Wadati : It is hoped so.

Prof. Benioff : Will you give magnitudes ?

Dr. Wadati : I will try.

Dr. Fr. Press : Hokkaïdo is out of balance isostatically, yet it is not seismically active. This is very strange.

Prof. Vecchia : Is the greatest Bouguer anomaly where the largest shocks occur ?

Prof. Tsuboi : In Hokkaïdo the situation is more complex East of Honshu. The intermediate shocks are on the steepest gradient of gravity.

104. — *La communication intitulée :* The Assam Earthquake of August 15, 1950 par *S. K. Pramanik* et *S. M. Mukherjee* est déposée sur le bureau.

A study of the Assam Earthquake, which occurred at 14 hrs. 9.5 m. G.M.T. on 15th August, 1950 has been made. Owing to the violence of the shock the seismographs at the Indian Observatories are incomplete, and a determination of the epicentre was made from the arrival times of P waves at observatories in India and some observation outside India distributed uniformly round the epicentral region. The epicentre is found to be at 28.6 N. and 96.5 E., and is in conformity with the direction of movement due to the earthquake experienced by observers over a fairly wide area to the south and southwest of the epicentre. The magnitude of the earthquake was 8.6, and a comparison with other earthquakes of magnitude 8 and above in different parts of the world showed that this is one of the greatest five earthquakes recorded in historic times. The energy of the earthquake was several million times that of an atomic bomb. An estimate of the acceleration produced in the epicentral region has been made, and is found to be about 5 g. The provision for acceleration due to earthquake required for engineering projects in different parts of India has been considered.

Le texte complet de la communication ci-dessus a été publié dans « *The Central Board of Geophysics* », *Publ. N° 1,* pp. 26-34, 9 figs.

En complément, *M. E. Peterschmitt* indique les résultats qu'il a obtenus en étudiant les répliques de ce grand séisme.

Du 15 août au 31 décembre 1950, les épicentres de 90 répliques ont pu être déterminés, dont 35% avaient une précision de ¼ de degré. La notion de réplique doit être prise dans un sens très large. La zone des épicentres s'étendant sur plus d'un million de km². La

magnitude des secousses a été déterminée d'après les inscriptions de Strasbourg et l'énergie a été calculée à l'aide de la formule

$$\log E = 12 + 1{,}8\ M$$

On constate que la somme des énergies des répliques est à peu près la millième partie de celle du séisme principal. Deux cartes de répartition géographique des répliques sont présentées, l'une en fonction de la magnitude, l'autre en fonction du sens du premier impétus (compression ou dilatation à Strasbourg). Enfin le graphique de Benioff (somme des racines carrées des énergies en fonction du logarithme du temps) est présenté.

Le *Dr. Bath* se référant à un travail présenté précédemment (4e séance) pense que la détermination de l'énergie pourrait être incertaine. Sa valeur absolue pourrait être connue à un coefficient 1.000 près.

M. *E. Peterschmitt* indique qu'il a trouvé de bons accords pour des énergies déclenchées au moment d'explosions et de coups de toit, le calcul étant effectué d'une part à partir des enregistrements séismiques, d'autre part à partir des données énergétiques. En utilisant la formule

$$\log E = 12 + 1{,}8\ M$$

l'accord est réalisé mieux qu'à une puissance de 10 près.

Le *Dr. Bath* mentionne la formule donnée dans la dernière édition de « Seismicity of the Earth » par B. Gutenberg et C. F. Richter :

$$\log E = 11 + 1{,}6\ M$$

ainsi que la formule qu'il a établie :

$$\log E = 10{,}2 + 1{,}8\ M$$

Le *Prof. Benioff* indique la formule utilisée tout récemment :

$$\log E = 9{,}0 + 1{,}8\ M$$

M. *E. Peterschmitt* pense que ce qui est important c'est que le coefficient de M semble être assez bien déterminé (compris entre 1,6 et 1,9). Dans l'établissement d'un graphique de Benioff, ce ne sont pas les valeurs absolues qui comptent, mais les valeurs relatives, de sorte que l'incertitude sur le coefficient constant ne joue pas un rôle important.

Le *Dr. De Bremaecker* demande si le mécanisme au foyer est responsable de ces incertitudes.

M. *Peterschmitt* pense qu'il en est probablement ainsi.

105. — Le *Dr. Shalem* présente sa communication intitulée : Séismicité et les cassures érythréennes dans l'Hinterland de la Vallée du Jourdain.

« L'étude macroséismique en Palestine, lorsqu'elle est faite avec la précision désirable par un réseau d'observateurs suffisamment serré, nous permet de découvrir les lignes tectoniques actives du pays.

L'expérience nous a montré que ces lignes sont des failles dirigées essentiellement : SE-NW (= érythréennes). Une part de ces cassures

constitue les fissures qui ont donné passage aux coulées de laves depuis le Néogène jusqu'à nos jours, et cela non seulement dans le proche Hinterland de la Vallée du Jourdain, mais aussi dans le Hedjaz.

L'étude séismologique nous indique entre autre que :

a) La Vallée du Jourdain n'est pas du point de vue séismologique une unité tectonique. Elle n'établit pas de foyers le long du Graben, mais seulement comme les coulées de lave aussi le long des lignes érythréennes qui croisent la vallée.

b) La principale ligne de partage des eaux palestiniennes est infiniment plus assujettie aux séismes qu'aux facteurs exodynamiques.

c) Les perturbations érythréennes se prolongent aussi dans le plateau continental méditerranéen.

La recherche séismologique éclaire le problème du volcanisme dans notre région érythréenne considérée comme une contrée éteinte. Toutefois, étant donné que nos séismes heurtent sans cesse les fissures et failles érythréennes, il n'est pas improbable que lesdites fissures s'entr'ouvrent et stimulent une activité volcanique paraissant aujourd'hui assoupie.

L'activité orogénique Alpo-himalayenne est le moteur commun à nos séismes et à ceux du Liban et de la Syrie. Cependant, du point de vue de la direction des perturbations dans ces dernières régions, on a constaté une différente combinaison des facteurs qui mène à une action séismique distincte, non érythréenne, comme c'est le cas des deux côtés de la Vallée du Jourdain. »

Le texte complet de la communication du Dr. Shalem est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Le *Père Plassard* fait remarquer que la distinction entre la Palestine, le Liban et la Syrie est aussi prouvée par le fait qu'un fort séisme palestinien a été très peu ressenti au Liban et en Syrie. Il est possible qu'il y ait deux étapes successives entre le type africain et le type anatolien.

106. — La communication intitulée : « On Phenomena Forerunning Earthquakes par *H. Sassa* et *E. Nishimura* » est présentée par le *Dr. Wadati.*

« The observation program and distribution of research observatories under our Institute for detecting any phenomena forerunning the occurrence of destructive earthquakes are described. And in this report some examples of the peculiar tilting motion and strain change of the ground intimately related to the occurrence of destructive earthquakes recently occurred in Japan are in some details discussed.

The minute but clear and characteristic tilting motion of the ground were observed *several hours* before the occurrence of Tottori Earthquake (September 10, 1943), Tônankai Earthquake (December 7, 1944) and Nanki Earthquake (April 26, 1950) at some observatories near their respective epicenters. On the other hand a large secular

tilting motion of the ground was observed with the tiltmeter at the station of Ogoya, 40 km distant from the epicenter, *three months* before the occurrence of destructive Daishoji-Oki Earthquake (March 7, 1952). And recently the peculiar tilting motion and strain change of the ground were concurrently detected by the tiltmetric and extensometric observation which appeared first gradually about *three months* and then rapidly *half month* before the occurrence of large Yoshino Earthquake (July 18, 1952). The observatories in this case are situated at Yura, Ide and Osakayama whose epicentral distance are 55 km, 72 km and 94 km respectively.

The order of magnitude in change of ground-tilt and -strain observed at the observatories near the epicenter of within 100 km-distance and discussed as the forerunner in the present treatment were estimated to be nearly one tenth second in angle of ground-tilt in case of several hours' forerunning and nearly several seconds in case of several days'. And the gradual change of ground-tilt and -strain observed several months before the earthquake-occurrence were diversely detected in their magnitude corresponding to their epicentral distance, the magnitude and focal depth of earthquake, and moreover the azimuthal difference of the observatory for the epicenter. Their amount were from several to several scores seconds in angle of ground-tilt and several millionth of length change in ground-strain. »

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Dr. Carder : Following the example of the Japanese, tiltmeters were installed along the Haywards Fault in California by the U. S. Coast and Geodetic Survey in cooperation with the University of California. At one station heavy tilts as high as 30" of arc were experienced during a rain. This tiltmeter was a better indicator of rain than a forecaster of earthquakes. One tiltmeter recorded once each hour. In 1937 an earthquake occurred on the fault, epicenter about 3 km N. W. of the station. The tilt pictures before and after the earthquake were almost identical. The results therefore were negative. It is to be remembered that faults in California are of the strike slip variety.

107. — M. *E. Peterschmitt* présente sa communication intitulée : La constitution physique de l'écorce terrestre en Europe occidentale.

« Les résultats fournis par les grandes explosions européennes (Heligoland, Haslach) sont en opposition avec toutes les théories énoncées jusqu'à présent sur la base des études des séismes rapprochés européens.

L'étude des inscriptions d'un certain nombre de séismes a montré qu'il était possible de mettre en évidence dans le groupe des ondes Pg, deux ondes distinctes : le premier Pgr (r = rapide) se propage avec une vitesse voisine de 6,0 km/sec., mais disparaît à une distance de l'ordre de 400 km; le deuxième Pgl (l = lent) se propage avec la vitesse classique de 5,6 à 5,7 km/sec. Aux courtes distances,

l'inscription de l'onde Pgl est souvent perturbée par l'onde Pgr qui la précède immédiatement.

Les épaisseurs des couches sont les suivantes :

gr = 2-10 km.

gl = 10-18 km.

La base de la couche g (= gl + gr) est située à une profondeur assez constante de l'ordre de 20 km. La couche « basaltique » sous-jacente a une épaisseur de l'ordre de 10 km. Il en résulte que le désaccord entre l'interprétation des séismes rapprochés et des explosions disparaît. Si l'interprétation de certains séismes soulève des difficultés, il n'est pas nécessaire de faire appel à un « low velocity channel » tel que l'a fait le Prof. Gutenberg pour la Californie. »

Le *Prof. Caloi* attire l'attention sur le grand nombre de questions qui ne sont pas encore résolues. Différents facteurs rendent les études des séismes rapprochés particulièrement délicates. L'influence des ondes évanescentes apparaissant à la surface de séparation de deux milieux doit être importante.

108. — Le *Prof. Dilgan* présente la communication intitulée : Le tremblement de terre de Yenidjé, le 18 mars 1953 par *H. Dilgan* et *T. Hagiwara.*

Un tremblement de terre destructif s'est produit aux environs de Yenidjé (commune du Vilâyet de Tchanakkalé), le 18 mars 1953, à 19 h. 06 m. 12 s. (G.C.T.). Yenidjé (39° 47' N lat., 27° 21' E long.), se trouve à peu près à l'intersection de la ligne Bandirma-Edremit et de Tchanakkalé-Balikesir. La magnitude de ce violent séisme avait été estimée à 7¾ (Pasadena) ou à 8 (Berkeley), et l'intensité dans la région épicentrale (Mercalli-Sieberg) est appréciée X.

L'arrondissement situé au Sud-Ouest du détroit des Dardanelles avait été fortement ébranlé et les dégâts ont été sévères dans plusieurs endroits, surtout à Yenidjé, à Tchan et à Gönen. Plus de 8.000 habitations ont été totalement détruites ou endommagées partiellement. Le nombre total des victimes s'élevait à 250.

La distribution de l'intensité de ce tremblement d'une assez large zone de perceptibilité avait été étudiée en détail par des missions de l'Institut Séismologique.

Les isoséistes tracées d'après une étude sur le terrain et selon les publications des journaux du pays, ont des formes assez irrégulières.

Le phénomène le plus intéressant du point de vue tectonique (selon Dr. Roesli et Prof. I. Ketin, tectoniciens de l'Institut) est la faille récente de 40 à 50 km qui s'est ouverte entre Gönen et Yenidjé, et qui est caractérisée par un déplacement horizontal et par des fissures. Ces fissures ouvertes s'arrangent plus ou moins diagonalement à la direction générale de la dite faille. Cette faille marque nettement la limite de deux blocs qui ont bougé en direction opposée l'un à l'autre. Le déplacement a été mesuré par Roesli et Dilgan en plusieurs endroits. Dans la vallée de Yenidjé, la route principale de Balikesir à Tchanakkalé a été coupée en biseau et à l'Est de Yenidjé nous avons mesuré un déplacement de plus de 3 m. La longueur de

la fissure qui suit à peu près la ligne de la faille et passant par Karaköy, Tchakir, Seyvan et Yenidjé était plus de 10 km. Il est aussi intéressant de noter que la dite faille ne suit pas la ligne des sources thermales Ilidja-Hidirlar qui est située à quelque distance au Sud-Est. C'est bien possible que cette faille récente a suivi la ligne de failles préexistantes.

Une investigation plus détaillée, du point de vue séismologique, du tremblement de terre de Yenidjé sera effectuée par l'Institut Séismologique de l'I.T.U. à l'aide des séismogrammes des diverses stations séismologiques mondiales.

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Le *Dr Lahn* pense qu'il faut être très prudent au sujet des conclusions tirées de l'étude des renversements de colonnes.

Le *Prof. Dilgan* indique qu'il a surtout tenu compte des colonnes posées sur le sol sans scellement.

109. — Le *Dr N. Pinar* présente sa communication intitulée : The Earthquake of Yenice-Gönen, Northwestern Turkey, March 18, 1953.

« This earthquake is interesting because of its high intensity magnitude : 7¾), the extent of damaged area (30.000 sq.km.), the amount of damage and number of casualties (more than 3000 buildings destroyed or heavily damaged, an equal number of houses lightly damaged and about 250 persons killed; the costs of the reconstruction work have depassed 12 Million of TL). It struck the peninsula of Çanakkale (the northwestern promontory of Asia Minor) and the neighbouring regions situated between the Sea of Marmara and the northern Aegean Sea.

In a tectonic analysis recently published I have attributed the Çanakkale peninsula to the « Aegean folds », intermediate folds intersected between the main folds of northern and southern Anatolia. These intermediate folds follow the Anatolian coast of the Aegean Sea. The orogenic folding phase creating the alpine ranges of Anatolia was succeeded by an epirogenic phase well developed in our region as elsewhere in Anatolia. During this phase the Marmara and Aegean basins have broken down only in a very recent period and a veritable network of epirogenic structures (faults and grabens) has been formed in this region.

As a result of these orogenic and epirogenic movements, our region has been divided into a succession of large anticlinal structures (plis de fond) consisting of Paleozoic, Mesozoic and Eocene rocks intersected by systems of faults or by grabens and basins filled with Neogene and Quaternary deposits and partly covered by Neogene lavas and tuffs. Hence, proceeding from southeast to northwest, we can distinguish a series of structures running from northeast to southwest; they are therefore more or less parallel to the neighbouring alpine folds, showing a close relationship between orogenic and epirogenic movements. These structures have been cut

by others, crossing the alpine structures perpendicularly or obliquely (east - west and north - south structures).

I described the most important seismic lines of the Marmara basin in 1942 and those of the Aegean region in 1949. To the lines previously known I have added other seismic lines, taking into consideration the tectonic structures and the features of the thermal and mineral hydrology. Among these « supposed » lines are the lines of Yenice - Gönen, of Çan and of Ezine-Lâpseki (lines VIII, VII and VI in my paper of 1942). Movements along the line VIII provoked the catastrophe of March 18, and secondary shocks (jeu en relais) on the lines VII and VI have also caused major damage. These lines have proceeded from the state of « possibility » to « reality ».

That it is the line VIII Yenice - Gönen which has produced the fundamental shock is proved by the map of isoseists which I have established, and also by the long earthquake fault opened between Yenice and Gönen as a surface expression of the deep tectonic dislocation.

The « pleistoseistic zone » (from 50 to 90 per cent of all buildings destroyed or badly damaged) is strongly localized along the Yenice - Gönen fault, where it forms a narrow ribbon. At Çan and in the northwest of Gönen, near Ulukir, where a new hot spring flows as a result of the shock, two little pleistoseistic nuclei have been pointed out. They are in relation with my tectonic line VII, the northeastward extension of which to the valley of the Gönen Çay is shown by the earthquake of March 18. A zone with 15-50 per cent of damage surrounds the pleistoseistic region. Sporadic instances of damage have been noted also at Çanakkale, Ayvacik and Ayvalik; they underline fault VI and the N-S faults of the Aegean coast.

A large zone with 1-15 per cent damage extends southwestward to Edremit and Ayvalik. Isolated localities showing more or less severe damage are scattered over the region beyond the limits of this zone (for instance in the districts of Gelibolu, Imroz, Bayramiç and Bergama). The chief causes of this damage are unfavorable local conditions.

The earthquake fault of Yenice - Gönen shows the classic characteristics : its extension is more than 80 km. Vertical and horizontal displacements offsetting roads, fences and even creeks have occurred along this fault.

Following the studies in the field, I have proposed that the epicenter of the earthquake must have been at Yenice. This is confirmed by the determinations given by distant observatories :
Coordinates of Yenice : 39° 9 N, 27° 3 E.

Coordinates of the epicenter :

U.S.Coast and Geodetic Survey (provisional epicenter) 40° 0 N, 27° 5 E
B.C.I.S. ..... 40° 1 N, 27° 3 E
F. Neumann (personal interpretation) ..... 39° 8 N, 27° 3 E»

Le texte complet de la communication du Dr. N. Pinar est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Le *Dr. Lahn* ajoute que la reconstruction dans la région de Gönen a posé des problèmes très graves.

M. l'*architecte Sargin* montre des photos de constructions nouvelles.

M. *Tixeront* demande s'il y a eu des phénomènes hydrauliques.

Le *Dr. Lahn* précise que certaines sources ont tari, d'autre part, une nouvelle source chaude est apparue. Le débit d'un puits artésien a augmenté. Les sources chaudes peuvent jouer un rôle important pour fixer une ligne tectonique.

Le *Dr. Grenet* a constaté que pour ce séisme, les S sont arrivés trop tôt à Alger. Il pense que le mécanisme de la faille doit s'étendre en profondeur.

110. — Le *Prof. J. Debrach* présente sa communication intitulée : Sur quelques alignements séismiques remarquables du Maroc. Essai d'interprétation tectonique.

« Les épicentres des principaux séismes survenus au Maroc au cours des vingt dernières années paraissent s'ordonner sur quelques alignements rectilignes remarquables.

On peut les ranger en deux groupes, chacun d'eux comprenant une direction principale recoupée à angle droit par des lignes secondaires.

L'un de ces alignements principaux s'oriente du SW au NE à peu près parallèlement à la direction générale des plissements atlasiens: le second est orienté du SSW au NNE dans la direction approximative des principaux axes tectoniques hercyniens du Maroc occidental. Cette dernière direction est également celle de la grande fracture de la Moulouya (Gauthier et Russo), ainsi que celle des géosutures transversales décrites par Glangeaud comme l'un des éléments marquants de la mosaïque tectonique nord-africaine. Ces grandes lignes de dislocation déjà avérées au Secondaire seraient des géosutures profondes affectant le socle lui-même et fort anciennes (Primaires ou Antécambriennes).

Il est curieux de remarquer que les deux réseaux d'alignements séismo-tectoniques décrits paraissent se recouvrir aussi exactement que possible par une rotation d'environ 30° dans le sens « dextrorsum ».

Une hypothèse est proposée pour interpréter la répartition de ces alignements, mais on peut en tous cas retenir le fait que les épicentres des principaux séismes marocains se groupent sur un ensemble de lignes qui paraissent nettement en rapport avec la mosaïque structurale de la région. »

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques*, fascicule N° 19.

Le *Prof. Rothé* pense qu'il faut être très prudent dans le tracé des alignements. Il y a trop peu de points et les épicentres sont déterminés avec trop peu de précision.

Le *Prof. Glangeaud* attire l'attention sur l'accident de direction méridienne, qui paraît avoir joué lors du séisme récent d'Orléansville, à l'intersection avec le géanticlinal de la zone III défini par

l'orateur. Il y a en Afrique du Nord de nombreux accidents de direction SSW - NNE, par conséquent en parallèles aux lignes mises en évidence par le Prof. Debrach.

111. — Le *Dr. De Panfilis* présente sa communication intitulée : Rilevamenti macrosismici per il territorio italiano del 1930 al 1952.

Il s'agit d'une étude macroséismique des tremblements de terre qui se sont produits en Italie pendant la période 1930-1952 et qui dans la zone épicentrale ont atteint des intensités du X^{e} au VI^{e} degré de l'échelle Mercalli. L'étude se compose de deux parties. L'une a abouti au tracé d'une série de cartes isoséistes (jusqu'au degré IV) ; les isoséistes de degré inférieur, pour lesquelles les données sont généralement rares et douteuses, ont été négligées. L'autre partie comporte l'établissement d'un catalogue chronologique des séismes correspondants avec des renseignements macroséismiques pour chacun d'eux. L'examen des diverses cartes permet pour une zone déterminée de déterminer l'activité séismique à laquelle a été soumise cette zone dans la période considérée, activité due aussi bien aux secousses chorocentriques qu'à celles ésocentriques.

L'activité séismique en Italie de 1930 à 1952 s'est manifestée par un total de 165 secousses ; l'une d'elles fut du degré X, 3 du degré IX, 15 du degré VIII, 44 du degré VII et 102 du degré VI. La région la plus active a été celle des Marches, puis la zone des Alpes Carniques, celle du Monte Amiata en Toscane, les Apennins de la Toscane et de la Romagne, les Apennins des Abruzzes, la zone de l'Irpinia. Une remarquable activité séismique a eu lieu aussi dans les régions du Gargano et de la Capitanata (Pouilles).

Le texte complet de la communation de M. De Panfilis sera publié ultérieurement en langue italienne dans « *Annali di Geofisica* ».

112. — Le *Dr. L. Marcelli* présente la communication intitulée : « Uno studio sul terremoto di Cefalonia (del 12 agosto 1953) con particolare riguardo alla natura fisica della scossa all'ipocentro » par *D. Di Filippo* et *L. Marcelli.*

Dans le but de commencer une étude sur la structure de la croûte terrestre qui correspond à la zone ionienne voisine de la Grèce, on a calculé l'épicentre d'une des secousses séismiques : cette secousse est la plus forte de toutes celles qui se sont produites, en août 1953, dans les Iles Ioniennes.

En outre, après avoir établi que le mouvement en question a été causé par un effondrement, on a comparé ce résultat à ceux qu'on a obtenus en étudiant les tremblements de terre qui se sont produits dans le nord de la Mer Adriatique et dans la chaîne des Apennins. En complétant cette étude par des données géologiques, on remarque que tous les effondrements de la Mer Adriatique — qui se rattachent probablement aux soulèvements des Apennins — s'alignent le long de l'axe synclinal formant la fosse Adrio-Ionienne.

De plus, il ne faut pas exclure la possibilité que le phénomène séismique puisse se rattacher à l'histoire géologique de l'Egéide.

Le texte complet de la communication de MM. D. Di Filippo et L. Marcelli a paru en langue italienne dans « *Annali di Geofisica* », vol. VII, N° 4, 1954, pp. 547-561, 5 fig.

La séance est levée à 12 h. 00 m.

DIX-HUITIÈME SÉANCE

JEUDI, 23 SEPTEMBRE (après-midi)

Programme

16. — Communications scientifiques : Divers.

113. — *K. Jung :* Remarks on the Foundation of the Conception of Isostasy.

114. — *H. Miki:* Grüneisen's Parameter and the Depth of isostatic Compensation.

115. — *A. R. Ritsema :* The Sense of the Principal Shearing Stresses in the Tonga Kermadec Salient.

116. — *V. Kárnik :* Velocities of Seismic Waves from Blasts in Bohemia.

117. — Mme *H. Labrouste :* Résultats collectifs de mesures séismiques à l'occasion de fortes explosions.

118. — *S. K. Guha, Gurdas Ram* and *G. V. Rao :* Trigger causes in Earth Movements.

119. — *M. J. Innes, P. L. Willmore* and *J. F. Clark :* Geophysical Investigation of a possible Meteorite Crater at Brent, Ontario, Canada.

120. — *S. Gershanik :* Improvements on the Estimate of Seismic Charges.

20. — Examen des Résolutions et vœux de l'Association.

21. — Constitution des Commissions de l'Association.

22. — Discussion d'un vœu du Rev. Père Ingram, S. J.

23. — Clôture de l'Assemblée Générale de l'Association.

La séance est ouverte à 14 heures.

16. Communications scientifiques : Divers

113. — Le *Prof. K. Jung* présente sa communication intitulée : Remarks on the Foundation of the Conception of Isostasy.

The usual isostatic reductions correspond nearly, but not exactly, to the physical principle of hydrostatic equilibrium beneath the

earth's crust. An exact reduction, however, should be performed in such a way that, if hydrostatic equilibrium exists in the actual earth, it is not disturbed by the reduction's displacement of masses. A perfect isostatic reduction requires that the level layers beneath the crust remain unchanged. It is possible to connect such a reduction with the equality of the topographic mass and its compensation. The reduction seems to be laborious. But one can show, that known tables may be used for a less difficult and satisfying approximation.

This reduction method has some advantages. The anomalies strictly correspond to the deviations from a physically well defined state and immediately lead to an estimation of the forces tending to reestablish hydrostatic equilibrium, and all difficulties concerning the displacement of subcrustal level surfaces are avoided.

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Prof. F. A. Vening-Meinesz points out that the conception of Prof. K. Jung, which requires lateral displacements of crustal masses, seems to be rather artificial and the earth crust tends to a state of hydrostatic equilibrium with deformed equipotential layers below the crust.

Prof. K. Jung maintains his opinion that his principle which avoids deformations of deep seated equipotentials and masses may be considered as more natural.

Prof. Vening-Meinesz does not agree.

114. — La communication du *Dr. H. Miki* intitulée : Grüneisen's Parameter and the Depth of Isostatic Compensation est déposée sur le Bureau.

The Grüneisen's parameter is defined as

$$\gamma_G = -\frac{\partial \log \nu_m}{\partial \log V} \qquad (1)$$

$$\nu_m = \left(\frac{9\, N_L}{4\,\pi\, V} \; \frac{1}{\frac{1}{v_P^3} + \frac{2}{v_S^3}} \right)^{\frac{1}{3}} \qquad (2)$$

We divide the earth's crust and mantle into a number of strata and assume that neither the crystal structure nor composition of the material changes within these strata and that the Grüneisen's parameter is constant in each stratum. Then from (1) and (2), we get

$$\frac{\left(\frac{1}{v_P^3} + \frac{2}{v_S^3}\right)_1}{\left(\frac{1}{v_P^3} + \frac{2}{v_S^3}\right)_2} = \left(\frac{V_1}{V_2}\right)^{3\gamma_G - 1} \qquad (3)$$

where the suffixes 1 and 2 correspond to the upper and the bottom surfaces of the stratum under consideration respectively.

$$-g\rho = \frac{dP}{dr} = \frac{\partial P}{\partial \rho}\frac{\partial \rho}{dr} + \frac{\partial P}{\partial T}\frac{dT}{dr} \quad (4)$$ (Condition of hydrostatic equilibrium)

$$\frac{\partial P}{\partial \rho} = \frac{K}{\rho} = v_P^2 - \frac{4}{3}v_S^2 \quad (5)$$

$$\frac{\partial P}{\partial T} = \frac{C_v \gamma_G}{V} \quad (6)$$

From (4), (5) and (6), we get the following equation :

$$-\frac{g}{2}\left(1 + \frac{V_2}{V_1}\right) = \frac{K}{\rho}\frac{1 - \frac{V_2}{V_1}}{r_2 - r_1} + \frac{2 C_v \gamma_G}{1 + \frac{V_1}{V_2}}\frac{1}{\lambda A}\frac{T_2 - T_1}{r_2 - r_1}$$

If the following four conditions, viz.,

(1) $\frac{dT}{dr} < 0$, that is, the temperature increases with increasing depth,
(2) the crustal structure and composition of material do not change in any stratum,
(3) Grüneisen's parameter has no extraordinary value,
(4) the condition of hydrostatic equilibrium is satisfied,

are satisfied in the interval of integration between 1 and 2, then it follows from (7) that the following inequality must hold in that interval :

$$\left| -\frac{g}{2}\left(1 + \frac{V_2}{V_1}\right) \right| > \left| \frac{K}{\rho}\frac{1 - \frac{V_2}{V_1}}{r_2 - r_1} \right|$$

Both sides of the above inequality can be evaluated from observed velocities of seismic waves propagated through the earth's interior.

The first three conditions are denied from various considerations and the results of calculations show that the condition of hydrostatic equilibrium is satisfied beneath the depth of 90 km from the earth's surface. This depth can be interpreted as representing that of the isostatic compensation. The value of 90 km was deduced by using the velocities of seismic waves in Japan, so that it can claim no general validity. Nevertheless this line of approach may afford a new method for estimating the depth of compensation from data other than gravimetric.

115. — La communication du *Dr. A. R. Ritsema* intitulée : The Sense of the Principal Shearing Stresses in the Tonga Kermadec Salient est déposée sur le bureau.

The directions of the first movements of the P and PKP waves of 105 earthquakes of the Tonga-Kermadec salient, as can be found in the I. S. S. Bulletins of the years 1935-1943, are the base of this study. It seems to be possible that 75 of these shocks are caused by a shearing stress system with its principal components in directions Up-Down, ENE-WSW and SSE-NNW. It is not proved that the other 30 earthquakes are not caused by this shearing stress system. 6 Types of earthquake mechanisms occur according to the relative size of the three principal stress components.

Assuming that the actual shear plane is that one which makes the smallest angle with the greatest shearing stress component, the following 6 positions of the shearplane seem to be possible in this zone.

Shallow earthquakes :

I Strike SSE-NNW, dip 35° WSW (thrust faults)
II Strike ENE-WSW, dip 80° SSE (normal faults)
III Strike NNE-SSW, dip 90° (clockwise strike-slip faults) or
Strike ESE-WNW, dip 90° (anti-clockwise strike-slip faults).

Deep earthquakes :

I Strike SSE-NNW, dip 55° ENE (normal faults)
II Strike ENE-WSW, dip 35° SSE (thrust faults)
III Strike NNE-SSW, dip 90° (anti-clockwise strike-slip faults) or
Strike ESE-WNW, dip 90° (clockwise strike-slip faults).

Shocks of System I are by far the most common. In both Systems I and II the normal fault earthquakes are the more common, suggesting that vertical pressures are the most active in generating earthquakes.

Tangential compressions are more common within the earth's crust than below, vertical compressions are more common below the earth's crust than within. This is in accordance with the contraction theory of the earth with a level of no strain, very near to the boundary between crust and mantle.

Le texte complet de la communication ci-dessus a paru dans « *Indonesian Journal of Natural Science* », Vol. 110, N° 4, 5, 6, June-December 1954, 5 fig., Bandung.

116. — La communication du *Dr. V. Kárnik* intitulée : Velocities of Seismic Waves from Blasts in Bohemia est déposée sur le bureau.

Seismograms of four seismological stations — Praha, Collm, Stuttgart and Jena — recorded from 38 quarry blasts in Bohemia during 1950-1954 were investigated. From the travel time curves the following average velocities of principal phases were found :

P : 5,62 km/sec.
P^x: / 6,82 / km/sec
S : 3,30 km/sec
S^x: 3,67 km/sec

X_1 : 4,03 km/sec.
X_2 : 2,78 km/sec
X_3 : 2,48 km/sec
X_4 : 2,10 km/sec
X_5 : 1,81 km/sec
X_6 : 1,61 km/sec

The time of explosion was controlled by a chronometer, but in several cases the required precision (± 0,1 sec.) could not be guaranteed, the majority of observations were from distances $\triangle <$ 110 km so that the travel time curves for P^x and S^x were not so certain as for other phases. The « Conrad discontinuity » is at a depth between 9 km from S^x and 14 km from P^x respectively.

The individual phases have certain characteristic features : the phase S is for distances $\triangle <$ 50 km very weak and doubtful, in greater distances it is more intensive; X_2 - X_6 at $\triangle <$ 60-80 km are very remarkable waves with greater periods; they could be interpreted as slow waves in surface layers or as reflexions on deeper discontinuities.

Le texte complet de la communication du Dr V. Kárnik est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

117. — Résultats collectifs de mesures séismiques à l'occasion de fortes explosions.

Au nom des différents auteurs *Mme Labrouste* résume l'ensemble des communications suivantes :

1° Inscription d'ondes séismiques causées par de grandes explosions: Camargue, 1949, par Y. Beaufils, P. Bernard, J. Coulomb, F. Duclaux, Y. Labrouste, H. Richard, E. Peterschmitt, J. P. Rothé et R. Utzmann.

2° Inscription d'ondes séismiques causées par de grandes explosions: Champagne, octobre 1952, par Y. Beaufils, J. Coulomb, R. Géneslay, G. Jobert, Y. Labrouste, E. Peterschmitt et J. P. Rothé.

3° Réflexions à grande profondeur, observées en Champagne, octobre 1952, par R. Géneslay, Y. Labrouste et J. P. Rothé.

4° Réfractions multiples observées dans l'inscription des explosions de Champagne, octobre 1952, par Y. Labrouste et Y. Beaufils.

5° Etude des ondes superficielles engendrées par les explosions de Champagne, octobre 1952, par Y. Beaufils.

La Compagnie Générale de Géophysique et les Instituts de Physique du Globe de Paris et de Strasbourg ont collaboré en 1949 et en 1952 à des expériences organisées à l'occasion de la destruction d'explosifs. Les charges utilisées variaient entre une centaine de kilogs et 10 tonnes.

En 1949 un profil de réfraction séismique long de 26 km a été mesuré en direction Nord-Sud à travers le delta du Rhône au Sud d'Arles (Camargue). En 1952 un profil de réfraction séismique a été tracé dans le Bassin parisien, en Champagne, au Sud de Reims. Ce profil, long de près de 100 km, était orienté à peu près E-W.

Le fait le plus notable est la mise en évidence dans les deux cas d'une onde dont la vitesse de 6,0 km/sec. est parfaitement définie. L'onde se propageant à cette vitesse est facile à percevoir sur les séismogrammes, car sur toute la longueur des profils elle constitue le premier impetus à partir d'une distance de 4 km en Camargue, de 10 km en Champagne. Il est probable que cette onde caractérise en

Camargue comme en Champagne le socle paléozoïque granitique ou métamorphique. L'ordonnée à l'origine de son hodochrone 0^s, 87 en Camargue, 0^s, 985 en Champagne dépend de l'épaisseur et de la nature des terrains sédimentaires sus-jacents. Le calcul de cette épaisseur est difficile à faire exactement. Plusieurs ondes réfractées dans les terrains sédimentaires peuvent être décelées, cependant leur interprétation précise reste sujette à caution, car ces ondes émergent en général après l'onde à grande vitesse. Des réfractions multiples compliquent l'interprétation.

On peut estimer que l'épaisseur des terrains sédimentaires est inférieure à 2.000 m en Camargue, voisine de 3.000 m en Champagne.

Un autre fait est l'existence d'une onde superficielle donnant des maxima d'amplitude très nets sur les enregistrements et qui se propage avec une vitesse apparente très faible en Camargue 500 m/s, une vitesse un peu plus élevée en Champagne (900 m/s). D'après l'étude de détail qui en a été faite par Mlle Beaufils, il s'agit d'ondes de Rayleigh. Cette onde superficielle à grande amplitude et à faible vitesse se retrouve également dans les enregistrements de l'explosion accidentelle du Fort Foch à Strasbourg et des coups de toit des mines de Lorraine.

Enfin pour répondre au vœu émis par la Commission Séismologique Européenne dans sa réunion de Stuttgart en septembre 1952, la C.G.G. a essayé à l'occasion de la deuxième série d'expériences d'enregistrer des réflexions profondes. Sur deux des films correspondant à l'enregistrement d'explosions de charges de 5 et de 10 tonnes des reprises d'énergie assez nettes peuvent être interprétées comme des arrivées d'ondes réfléchies les unes sur une surface située à 11 km de profondeur et les autres sur une surface située à environ 31 km de profondeur. Ces données numériques sont naturellement approximatives en raison même de l'incertitude sur les valeurs à adopter pour les vitesses moyennes dans les différentes couches (6,0 kms pour la « couche granitique », 7,0 pour la couche sous-jacente basaltique).

Les communications présentées par Mme Labrouste sont destinées à être insérées dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques,* fascicule N° 19.

Prof. J. T. Wilson asks : Were good second P arrivals observed from various layers and is Mme Labrouste satisfied that there are really five layers ?

Mme Labrouste : The explanation we have given appears to be the best.

Rev. Dr. Ingram : This is the same question as that proposed by Messrs. Tatel and Tuve.

Prof. Wilson agreed.

113. — La communication intitulée : Trigger causes in Earth Movements by *S. K. Guha Gurdas Ram* and *G. V. Rao* est déposée sur le bureau.

Characteristics and nature of a large number of very small shocks occurring in swarms in the Himalayan region have been examined

with reference to change in frequency, of their occurrence, origin and to other regional characteristics. A close scrutiny has revealed that triggering forces released due to rate of change of flood intensity enhance the frequency of occurrence of these small shocks, especially during rising and falling parts of the hydrographs. Possible association of the zones of the Himalayan boundary fault with the origin of these small shocks has also been discussed. Further, it has been held possible that occurrence of these small shocks, in swarms, may be one of the characteristics of unstable geological formations as also evidenced from a large number of destructive shocks.

Le texte complet de la communication ci-dessus est destiné à être inséré dans les *Publications du Bureau central séismologique international, Série A, Travaux Scientifiques*, fascicule N° 19.

119. — Le *Dr J. S. Innes* présente la communication intitulée : Investigation géophysique d'un cratère probablement creusé par un météorite à Brent (Ontario) par *J. S. Innes, P. L. Willmore* et *J. F. Clark.*

Des investigations géophysiques et autres appuient la théorie d'une origine météorique en ce qui a trait à une particularité topographique circulaire, d'un diamètre de 2 milles, qui se trouve à environ 3 milles au nord de Brent (Ontario), dans le parc Algonquin.

La partie centrale de cette particularité topographique est recouverte d'épais dépôts glaciaires. On a trouvé, dans la région, plusieurs spécimens de roches paléozoïques, mais il n'est pas certain que ces roches y étaient *in situ*. On a aperçu de nombreux affleurements de gneiss granitiques grenatifères et à hornblende sur les collines qui entourent cette particularité de terrain et qui s'élèvent à quelque 300 pieds au-dessus du bord.

Les résultats d'études sur la gravité montrent qu'il y a un minimum circulaire d'environ 5.2 milligals au-dessus de cette particularité, et que la matière à l'intérieur est de 0.17 à 0.31 gms par cc. moins dense que dans les gneiss granitiques qui l'entourent. Si l'on peut supposer que cette différence de densité persiste en profondeur, le fond non dérangé du cratère doit reposer entre 1.500 et 3.600 pieds au-dessous de la surface pour permettre d'expliquer cette anomalie de la gravité. L'anomalie de gravité négative semble démentir une origine volcanique en ce qui a trait à ce cratère.

Les observations d'ondes sismiques résultant de coups de mine tirés à intervalles en travers d'un diamètre ont été obtenues au moyen de 2 sismomètres radiographiques placés en dehors du bord du cratère. La courbe déplacement-temps a indiqué une épaisseur de matière (que l'on croit être formée de sédiments paléozoïques) allant jusqu'à 1,000 pieds, d'une vélocité de propagation d'environ 10,000 pi./sec. On a trouvé une épaisseur beaucoup plus considérable de matière ayant une vélocité d'environ 14,000 pi./sec. entre les sédiments et la matière type du bouclier canadien. On est d'avis que cette matière intermédiaire peut être formée de débris de l'explosion, qui se seraient depuis consolidés en brèche. L'épaisseur des sédiments indiquée par les observations sismiques n'est pas suffisante pour

expliquer l'anomalie de gravité observée; cependant l'effet de la brèche pourrait suffire à en expliquer la différence.

Les anomalies magnétiques verticales sont minimes et varient uniformément au-dessus du centre du cratère, indiquant une origine très profonde. Par contraste, les anomalies au delà du bord varient rapidement et tendent à suivre l'orientation structurale dominante du gneiss granitique.

Le texte complet de la communication ci-dessus est destiné à être inséré dans « *Publications of the Dominion Observatory, Canada* ».

Dr St. Amand asks : Is it possible to determine if the limestone is in place or not ?

Dr Innes : So far this particular outcrop has not been investigated.

Prof. Bullard : If the limestone is not in place, what would it mean ?

Dr Innes : Possibly it was brought down by glacier.

Prof. R. Ross Heinrich : In Missouri Dr. Fox has investigated Crooked Creek disturbance in Crawford County and has found a gravity anomaly over the disturbance. The anomaly is a gravity low. The magnetic survey results indicate some relation of the field over the disturbance to the surrounding tectonic trends.

A further comment on the question asked as to whether the limestone within the Brent Crater was really in place, was made by *Dr. C. S. Beals* of the Dominion Observatory. He pointed out that the Observatory organization was aware of the importance of this point and that the possibility was being considered of carrying out drilling operations to test this point.

120. — La communication du *Dr S. Gershanik* intitulée : Improvements on the Estimate of Seismic Charges est déposée sur le bureau.

Deformations u of buildings due to the acceleration of earthquakes are investigated. Two suppositions are made: a) the deformations are principally due to shear; and b) they are principally due to bending.

In both cases it is found that u may be expressed by a uniformly convergent series of eigenfunctions.

Except for a variable factor, the Fourier coefficients of these series are the same as the values X obtained recently by Alford, Housner and Martel, by means of the electrical analog computer of the California Institute of Technology.

Using mean values of what they call the spectrum of earthquakes, it is found that the seismic charge is constant on buildings less than 30 m height. On buildings higher than 30 m it becomes decreasing with height.

Le texte complet de la communication ci-dessus a paru dans « *Annali di Geofisica* », Vol. 8, 1955, pp. 181-188.

20. Examen des résolutions et vœux de l'Association

Le Président *Gutenberg* donne lecture des quatre résolutions qui ont été proposées par les Membres de l'Association. Ces quatre résolutions dont les textes anglais et français figurent en annexe aux pages 179-182 sont adoptées à l'unanimité.

Ces propositions seront transmises au Secrétariat Général de l'U.G.G.I. pour être présentées à l'Assemblée Générale de l'Union.

21. Constitution des Commissions de l'Association

a) *Commission de l'I.S.S.* — Le Président *Gutenberg* : It has been suggested that Dr. *Hodgson, Jr.* replace his father.

Cette proposition est adoptée et les autres Membres de la Commission sont maintenus en fonction.

b) *Committee on Physics of the Interior of the Earth.* — Prof. *Gutenberg* : If no changes are proposed I suggest that the former Members continue and prepare again the meetings.

Cette proposition est adoptée.

22. Discussion d'un vœu du Rev. Père Ingram, S. J.

I wish to propose that as often as possible stations record compressions and dilatations for all early phases (e. g. : P, pP, PcP, PP, pPP, PPP, etc...).

Prof. *Gutenberg* : Also, if possible, amplitudes of large movements.

Le vœu du Rév. Père *Ingram* sera publié dans le Bulletin Mensuel de l'Association.

23. Clôture de l'Assemblée Générale de l'Association

Prof. *Gutenberg* expressed his thanks to the Speakers who presented papers or participated in the discussions and made the meeting a very successful one. He thanked especially Prof. *Rothé* for his large work to prepare the meetings and to maintain a sound financial status of the Association. He finally thanked the Italian Committee preparing the meeting in Rome.

Dr. *Hodgson* added : I think we owe our thanks to Dr. *De Bremaecker* for his very valuable summaries and translations.

(Applause).

L'Assemblée Générale est déclarée close.

La séance est levée à 16 h. 30.

RÉUNIONS DU CONSEIL DE L'ASSOCIATION

Les représentants des différents pays au Conseil de l'Association sont :

ALLEMAGNE :	Dr. Tams
AUSTRALIE :	Prof. Bullen
AUTRICHE :	Dr. Toperczer
BELGIQUE :	M. Bourgeois
CANADA :	Dr. Hodgson
DANEMARK :	Mlle Lehmann
ESPAGNE :	Dr. Bonelli
ÉTATS-UNIS :	Prof. Gutenberg
	Dr. Heinrich
	Dr. Slichter
FINLANDE :	Dr. Vesanen
FRANCE :	Mme Labrouste
	Prof. Rothé
GRANDE-BRETAGNE :	Sir Harold Jeffreys
GRÈCE :	Prof. Galanopoulos
INDE :	Dr. Gulatee
IRLANDE :	Rev. Dr. Ingram
ISRAEL :	M. Shalem
ITALIE :	Prof. Calci
JAPON :	Dr. Wadati
MAROC :	Dr. Debrach
PHILIPPINES :	M. Banzon
SUÈDE :	Dr. Bath
SUISSE :	Dr. Wanner
TUNISIE :	Prof. Rothé
UNION SUD-AFRICAINE :	Dr. Hales

Le Représentant de la TURQUIE sera désigné ultérieurement.

Les pays suivants ne sont pas représentés : ARGENTINE, COLOMBIE, ÉGYPTE, INDONÉSIE, MEXIQUE, NORVÈGE, NOUVELLE-ZÉLANDE, PAYS-BAS, PÉROU, POLOGNE, PORTUGAL, SYRIE, TCHÉCOSLOVAQUIE, THAILAND, VIETNAM, YOUGOSLAVIE.

PREMIÈRE SÉANCE DU CONSEIL

MERCREDI, 15 SEPTEMBRE (matin)

La séance est ouverte à 11 heures sous la présidence du *Professeur Gutenberg,* Président de l'Association.

Sont présents : MM. M. Bath, J. Bonelli, J. Debrach, H. Dilgan, A. Galanopoulos, A. L. Hales, R. Heinrich, J. H. Hodgson, Rev. R. Ingram, S. J., Mme Y. Labrouste, Mlle I. Lehmann, MM. R. Stoneley, E. Tams, E. Vesanen, K. Wadati, E. Wanner.

Le *Professeur Rothé* informe le Conseil des questions à étudier d'urgence :

1) *Services Permanents.* La Réunion du Comité Exécutif de l'U.G.G.I., qui vient de se tenir, a mis en évidence les difficultés qui se présentent pour assurer un bon fonctionnement des sept Services Permanents de l'Union. Parmi ces Services figurent l'I.S.S. et le Bureau Central de Séismologie. Les subventions reçues de l'U.N.E.S.C.O. ont été fortement réduites. Il convient de chercher une solution à ces difficultés, et M. le Secrétaire Général de l'U.G.G.I. propose que les Services permanents soient fédérés en un service international qui pourrait prendre le nom de *Service International pour l'exploitation des données géophysiques.* On pourrait ainsi espérer recevoir des fonds spéciaux pour ce service international.

Le *Dr. Wanner* déclare que, si on peut approuver le principe de ce service, il faut cependant éviter que l'Administration ait une part prépondérante dans son contrôle; il convient que l'Union conserve une influence primordiale dans le fonctionnement du nouveau service.

Un échange de vues s'engage alors entre *MM. Jeffreys, Stoneley* et *Rothé.* Le *Dr. Hales* propose de laisser la liberté aux personnes plus directement intéressées.

Une résolution est prise déclarant que l'Association favorise la création du nouveau service et laisse au Bureau et au Directeur de l'I.S.S. le soin de négocier avec le Secrétaire Général de l'Union afin d'obtenir les garanties nécessaires.

2) *Publications de l'Association.* Le Secrétaire Général de l'Union propose que toutes les Publications soient confiées à un seul imprimeur (Butterworth à Londres). Les avantages présentés sont de divers ordres :

a) Toutes les publications de l'Union auraient la même forme;

b) Une plus grande publicité pourrait être assurée par la Maison d'édition et on pourrait espérer augmenter le chiffre de ventes, chiffre actuellement très bas. Par contre, cette méthode présente un désavantage notable. Il est en effet nécessaire de garantir à l'imprimeur une recette minima qui risque de ne pas être couverte par les ventes.

Le *Professeur Rothé* mentionne que de toute façon la Maison Butterworth ne songe pas à imprimer l'I.S.S. ni le Bulletin mensuel du Bureau Central. Pour notre Association il convient seulement de

savoir si l'impression des Comptes rendus des Assemblées et des « Travaux Scientifiques » doit être confiée à cette Maison.

Le *Dr. Stoneley* pense que la façon actuelle de procéder est adéquate.

Resolution: The question concerning the publications of the Union has been thoroughly examined by the Council.

In view of the small numbers of copies which could be sold it is very likely that a part at least of the guarantee should be paid and therefore the Association does not think that the commercial printing would reduce the present cost of its publications, so far as the Association of Seismology and Physics of the Earth's Interior are concerned.

Dr. Hodgson asks : Would we not have a large sale because we are concerned with the Interior of the Earth ?

Le Secrétaire Général fait remarquer que l'Association ne publie actuellement qu'un fascicule de « Travaux Scientifiques » tous les trois ans.

La résolution ci-dessus est adoptée à l'unanimité.

3) Limites entre les travaux des Associations de Géodésie et de Séismologie et de Physique de l'Intérieur de la Terre.

Le Secrétaire Général donne lecture de la correspondance qu'il a échangée avec le Secrétaire Général de l'Association de Géodésie. La question a été soulevée à la suite de l'envoi du programme préliminaire de notre Association qui prévoyait des communications intéressant la gravimétrie et la géodésie, communications qui devaient être présentées au cours de séances communes aux deux Associations.

L'Association de Géodésie a proposé de soumettre au Conseil de l'U.G.G.I. le règlement suivant :

Article 1. — Lors de chaque Assemblée Générale, il est organisé par entente directe entre les Bureaux des deux Associations de Géodésie et de Séismologie et Physique de l'Intérieur de la Terre un certain nombre de réunions communes auxquelles prennent part les Membres de ces deux Associations. Les ordres du jour en sont établis d'un commun accord. Les comptes rendus sommaires en sont publiés par l'une et par l'autre de ces Associations. Il en est de même des vœux et résolutions adoptés. Par contre certains Mémoires originaux sont publiés in extenso soit par l'une, soit par l'autre de ces Associations (après entente avec l'auteur). Ils sont seulement mentionnés ou sommairement résumés par l'Association qui ne s'est pas chargée de la publication. La même règle est suivie pour des articles paraissant en dehors des Assemblées Générales et publiés dans les organes officiels de l'une ou l'autre des Associations.

Article 2. — La *Gravimétrie* proprement dite reste du domaine propre de l'Association Internationale de Géodésie. Il est entendu par là les déterminations absolues et relatives de g (instruments, méthodes, mesures), la constitution d'un réseau gravimétrique homogène de mesures brutes. La Gravimétrie comporte également la réduction

des mesures au Géoïde (et par conséquent l'étude des anomalies correspondantes de la pesanteur) dans les hypothèses de caractère mathématique ou en tous cas schématique: air libre, plateau de Bouguer, correction topographique à densité homogène constante, correction isostatique dans les hypothèses classiques.

Article 3. — La *détermination du Géoïde* et de ses positions relatives par rapport à une surface théorique de référence reste également du domaine propre de l'Association Internationale de Géodésie. Il s'agit plus spécialement en ce cas d'une surface de référence *générale,* par rapport à laquelle sont déterminées les distances N au géoïde (par la formule de Stokes) ou l'angle des normales (déviations dites absolues de la verticale) par des formules dérivées de celle de Stokes. Mais il peut s'agir également de déterminations à caractère plus local faisant intervenir les positions relatives du géoïde et d'une surface située dans l'espace dans une position particulière (déviations dites relatives de la verticale par utilisation des résultats d'un réseau astronomico-géodésique, — opérations dites de Nivellement astronomique, — profils du Géoïde par distances zénithales réciproques, etc.). Enfin, l'Association Internationale de Géodésie s'intéresse aussi directement aux déviations absolues de la verticale par des méthodes astronomiques spéciales, telles que : éclipse de Soleil, occultations d'étoiles par la Lune et autres méthodes mettant en jeu le déplacement parallactique de la Lune observé à partir de points différents du Globe terrestre.

Article 4. — Doivent être, au contraire, considérées comme constituant un domaine commun aux deux Associations visées par le présent accord, et être discutées au cours des séances communes visées à l'article 1, toutes les questions concernant :

— Les interprétations géophysiques des anomalies de la pesanteur ou des déviations de la verticale (déviations absolues ou déviations relatives). Ces interprétations peuvent concerner aussi bien la Géologie profonde que la Géologie superficielle.

— L'étude critique des hypothèses qui sont à la base des méthodes de réduction des mesures de pesanteur ou des déviations relatives de la verticale. Une mention spéciale doit être faite ici des questions d'équilibre isostatique et des corrections tenant compte de la contexture géologique réelle (densités variables) aux environs des points de stations et aux diverses profondeurs.

— Toutes questions concernant la rigidité du globe terrestre, telle qu'elle peut être étudiée par la comparaison des valeurs théoriques et observées

a) soit des amplitudes des marées océaniques à longue période (?);

b) soit des amplitudes, sous l'effet luni-solaire, des déviations journalières de la verticale ou des variations journalières de l'intensité de la pesanteur;

c) soit des périodes principales de la polodie de l'axe de rota-

tion terrestre (1), telles qu'elles sont déduites du phénomène de variation des Latitudes.

— L'étude des questions intéressant les variations des densités à l'intérieur de l'écorce et l'existence de surfaces de discontinuité, telles qu'elles peuvent être déduites des synthèses d'observations séismologiques — et dans toute la mesure où la connaissance de ces phénomènes est susceptible de réagir sur la réduction des mesures gravimétriques ou astronomiques.

— Toutes questions concernant le défaut de stabilité de l'écorce telle qu'il peut être mis en évidence soit en surface par des déterminations géodésiques (triangulations, nivellements et mesures de distances zénithales répétés), — soit en profondeur (variations dans le temps de la verticale ou de l'accélération de la pesanteur).

Article 5. — Pour ne pas interrompre une série de *Rapports Généraux* remontant à plusieurs décades, l'Association de Géodésie continuera, comme elle le fait actuellement, à publier :

— un Rapport Général sur l'Isostasie embrassant tous les problèmes relatifs à cette question;

— un Rapport Général sur les *Marées terrestres,* dans les mêmes conditions que ci-dessus.

Elle mettra gratuitement à la disposition de l'Association de Séismologie et de Physique de l'Intérieur de la Terre un nombre suffisant de ces Rapports, qui pourront être distribués à toutes les personnalités scientifiques intéressées par ces problèmes et qui ne recevraient pas directement le Volume des Rapports Généraux publié par l'Association Internationale de Géodésie à l'occasion de chaque Assemblée Générale.

Il est probable que le Comité Exécutif de l'Union se déclarera satisfait du modus vivendi proposé.

Le règlement ci-dessus est approuvé par le Conseil de l'Association.

La séance est levée à 12 h. 30.

DEUXIÈME SÉANCE DU CONSEIL

JEUDI, 23 SEPTEMBRE (après-midi)

La séance est ouverte à 16 h. 45.

L'ordre du jour de la réunion appelle l'élection du Comité Exécutif de l'Association.

Le Secrétaire Général pense que la présence de l'ancien Président serait très désirable au sein du Comité Exécutif; de même il serait

(1) L'ensemble de ces questions est généralement désigné sous le nom de *Marées de l'écorce.*

bon qu'un représentant de l'Argentine, pays où doit se réunir la prochaine Assemblée Générale, fasse partie de ce Comité.

Sont élus à l'unanimité : MM. M. Bath (Suède), S. Gershanik (Argentine), B. Gutenberg (U.S.A.), J. H. Hodgson (Canada), Rev. Dr. Ingram (Irlande).

La séance est levée à 17 heures.

ANNEXE I

RÉSOLUTIONS

adoptées par l'Assemblée de Rome (1954)

ASSOCIATION INTERNATIONALE DE SÉISMOLOGIE

ET DE

PHYSIQUE DE L'INTÉRIEUR DE LA TERRE

RESOLUTIONS (English Text)

RESOLUTION 1.

Considering the great service to seismological research rendered by the epicenter cards issued so promptly by the United States Coast and Geodetic Survey, the U.G.G.I. resolves that the United States Coast and Geodetic Survey be urged to continue issuing these cards as at present and if possible that this service be improved, and be it further

Resolved that a copy of this resolution be sent to the Secretary of Commerce, U.S.A.

RESOLUTION 2.

That the Association of Seismology and Physics of the Earth's Interior considers that during the Geophysical Year full advantage should be taken of any opportunities that may occur of installing seismographs in such regions of the world as the Pacific and the Antarctic where, through the scarcity of stations, our knowledge of the seismicity is inadequate.

The Association further considers that valuable data on microseisms may thus be available, particularly in conjunction with oceanographical investigations.

RESOLUTION 3.

It is understood that the Australian Government may establish a magnetic observatory at Port-Moresby, New Guinea. In this event the U.G.G.I. strongly recommends to the Australian Government that steps be taken at the same time to set up a seismological observatory at Port-Moresby. This recommendation is made because of (1) the active seismicity of the New Guinea area; (ii) the extremely small number of seismological observatories in the whole Australian region. It is recommended that the equipment include an accurate time-service (this is of cardinal importance) and seismographs capable of recording the three components of earth motion from distant as well as near earthquakes.

RESOLUTION 4.

Considering the interest expressed as a consequence of the results on the basis of records of great artificial explosion, concerning the structure of the Earth's crust, the U.G.G.I. recommends that the governments of the countries in the Alpine zone aid in the organization of new systematic experiments using large explosive charges. The Commission Seismologique Européenne is in charge of the preparation of such experiments and the coordination of such investigations.

It is also desirable that similar studies should be carried out in other regions of the Earth, and specially in Japan.

The U.G.G.I. asks the Governments concerned to contribute to this research.

ASSOCIATION INTERNATIONALE DE SÉISMOLOGIE

ET DE

PHYSIQUE DE L'INTÉRIEUR DE LA TERRE

RÉSOLUTIONS

RÉSOLUTION 1.

Considérant le grand service rendu aux recherches séismologiques par les cartes de détermination d'épicentres diffusées par le United States Coast and Geodetic Survey, l'U.G.G.I. demande que ce service soit invité à poursuivre la diffusion de telles cartes et si possible que ce service soit développé, et pour qu'il en soit ainsi,

demande qu'une copie de cette résolution soit envoyée à Son Excellence, le Secrétaire au Commerce, Washington, U.S.A.

RÉSOLUTION 2.

L'Association de Séismologie et de Physique de l'Intérieur de la Terre considère qu'au cours de l'Année Géophysique il y aurait un grand avantage à installer des séismographes dans des régions telles que l'Océan Pacifique et l'Antarctique, où la rareté des stations rend actuellement insuffisante notre connaissance de la séismicité.

Par ailleurs, l'Association considère qu'au cours de l'Année Géophysique des données sur les microséismes devront être rassemblées particulièrement en liaison avec les recherches océanographiques.

RESOLUTION 3.

Le Gouvernement Australien ayant l'intention d'installer un observatoire magnétique à Port-Moresby, en Nouvelle Guinée, l'U.G.G.I. recommande très vivement au Gouvernement Australien de prendre des dispositions pour installer en même temps un observatoire séismologique à Port-Moresby. Cette recommandation est faite (1) en raison de la grande activité séismique de la région de Nouvelle Guinée; (ii) du très petit nombre d'observatoires séismologiques dans l'ensemble du domaine australien.

Il est recommandé que l'appareillage comprenne un service horaire précis (ce qui est d'importance capitale) et des séismographes capables d'enregistrer les trois composantes du mouvement du sol aussi bien pour les séismes proches que les séismes éloignés.

RÉSOLUTION 4.

L'U.G.G.I. constatant l'intérêt présenté par les résultats déjà obtenus à l'occasion de grandes explosions en ce qui concerne la structure profonde de l'écorce, recommande que les gouvernements des pays intéressés par la zone alpine participent à l'organisation de nouvelles expériences systématiques mettant en jeu de fortes charges explosives. La Commission Séismologique Européenne est chargée de l'organisation pratique des expériences et de la coordination des recherches.

Il est également désirable que des recherches du même genre soient effectuées dans les autres régions du monde et spécialement au Japon. L'U.G.G.I. prie les gouvernements de contribuer à cette étude.

ANNEXE II

RAPPORTS NATIONAUX

DES PAYS MEMBRES[1]

Allemagne	Israël
Argentine	Italie
Australie	Japon
Autriche	Maroc
Belgique	Nouvelle-Zélande
Canada	Pakistan
Colombie	Pérou
Danemark	Philippines
Espagne	Portugal
France	Suède
Grande-Bretagne	Suisse
Grèce	Tchécoslovaquie
Inde	Union Sud-Africaine
Indonésie	United States of America
Irlande	Yougoslavie

PAYS NON-MEMBRES (1)

Hongrie

(1) Au 1er juillet 1954; voir au verso la liste des pays adhérents à l'U.G.G.I. au 1er janvier 1955.

LISTE DES PAYS ADHÉRENTS A L'UNION GÉODÉSIQUE ET GÉOPHYSIQUE INTERNATIONALE

au 1er janvier 1955

Allemagne (Rép. Féd.)
Argentine
Australie
Autriche
Belgique
Bolivie
Brésil
Canada
Chili
Colombie
Danemark
Egypte
Espagne
Etats-Unis
Finlande
France
Grande-Bretagne
Grèce
Haïti
Hongrie
Inde
Indonésie
Iran
Irlande
Israël
Italie
Japon
Maroc
Mexique
Norvège
Nouvelle-Zélande
Pakistan
Pays-Bas
Pérou
Philippines
Pologne
Portugal
Soudan
Suède
Suisse
Syrie
Tchécoslovaquie
Thaïland
Tunisie
Turquie
Union Sud-Africaine
U.R.S.S.
Viet-Nam
Yougoslavie

ALLEMAGNE

BERICHT UEBER DIE TÆTIGKEIT AUF DEM GEBIET DER SEISMOLOGIE IN DER DEUTSCHEN BUNDESREPUBLIK VON 1951 BIS 1953

Der im Bericht über die Zeit von 1945 bis Anfang 1951 (welcher auf der Tagung der IUGG in Brüssel vorgelegt wurde) dargestellte seismische Dienst hat sich gefestigt und ist sachlich und regional weiter ausgebaut worden. Hinzugekommen sind die dem Geologischen Institut der Universität Köln im Rheinland angegliederten Erdbebenstationen in Bensberg (rd. 15 km östlich von Köln) und Mechernich (rd. 35 km südwestl. von Bonn) sowie eine Station in Münster (Westfalen) beim Geologischen Institut der dortigen Universität. Ausserdem ist die frühere Station des Instituts für Meteorologie und Geophysik der Universität Frankfurt am Main auf dem Kleinen Feldberg im Taunus wieder in Betrieb genommen.

Im folgenden seien zunächst nähere Angaben über die Ausrüstung und Tätigkeit der einzelnen Stationen gemacht. Am Schluß dieses Berichts findet sich wieder eine Liste der einschlägigen Veröffentlichungen deutscher Autoren.

1) *Göttingen.* Die Erdbebenwarte des Geophysikalischen Instituts der Universität (Leitung : Prof. Dr. J. Bartels) war mit den Wiechertschen Instrumenten laufend tätig. Die Untersuchungen über Tiefherdbeben nach den Göttinger Seismogrammen und über die Eigenschaften eines Schütteltisches wurden fortgesetzt. Ausserdem wurde ein Gerät für Nahbebenaufzeichnungen mit Magnet-Tonband-Registrierung entwickelt (H. Dörmann) und eine neuartige photographisch und mit Knallfunken arbeitende Apparatur für die Bestimmung der Wellengeschwindigkeiten in Gesteinsproben, welche dabei in eine Flüssigkeit getaucht sind, gebaut; diese Vorrichtung gestattet, kleinste Proben von 3 cm Länge zu untersuchen (E. Müller).

2) *Hamburg.* Die Hauptarbeit der Erdbebenstation des Geophysikalischen Instituts der Universität war unter der Leitung von Dr. H. Menzel in der Berichtzeit der Wiederherstellung und Inbetriebsetzung an ihrem neuen Ort in einem Bunker des Waldgebiets von Harburg gewidmet. Begonnen wurde mit der Aufstellung des astatischen Horizontalseismographen nach Wiechert (Masse 1.000 kg). Dieses Instrument registriert seit Juni 1952 laufend. Die Eigenperiode beträgt etwa 9 sec., das Dämpfungsverhältnis etwa 6:1 und die statische Vergrösserung etwa 220. Bei der Justierung des Instrumentes wurde besonderer Wert darauf gelegt, die Reibung der Schreibspit-

zen möglichst gering zu halten. Es wurde der Wert $r/To^2 = 0{,}005$ erreicht bei normaler Papiergeschwindigkeit von 15 mm/min.

Die Wiederherstellung des Wiechert - Vertikalseismographen (Masse 1250 kg) war im Mai 1953 beendet. Dieses Instrument hat eine Eigenperiode von ca. 5,0 sec., ein Dämpfungsverhältnis von ca. 6:1 und eine statische Vergrösserung von etwa 220. Der Wert r/To^2 liegt etwa bei 0,006.

Seit Juni 1953 wurden Einsatzzeiten von P und S von stärkeren Beben aus einer Epizentraldistanz kleiner als 5000 km durch Luftpost an das Bureau Central International de Séismologie in Straßburg mitgeteilt gemäß einem Beschluss der Europäischen Seismologischen Kommission aus dem Jahre 1952.

Nach Wiederaufstellung des Wiechertschen Vertikalseismographen wurde mit dem Bau eines kurzperiodischen elektro-magnetischen Vertikalseismographen begonnen nach dem Vorbild des kurzperiodischen Hiller-Seismographen, System Stuttgart. Die Konstruktion dieses Instrumentes wurde von Herrn Strobach durchgeführt und ist im wesentlichen abgeschlossen. Das Gerät wird ab Januar 1954 regelmäßig registrieren. Die Eigenperiode des Seismographen beträgt 1,9 sec, des Galvanometers 1,5 sec. Die Resonanzkurve ist sehr steil und hat ihr Maximum bei 1 sec, wo die Vergrößerung 6000 beträgt. Dämpfungen von Seismograph und Galvanometer sind kritisch.

Ferner wurden in der Berichtszeit eine Reihe von Feldseismographen gebaut. Für die Eichung des Instrumentariums wurde ein Schütteltisch konstruiert, mit welchem man Vertikalseismographen in dem Bereich von 0 bis 300 Hz eichen kann.

Zur Zeit wird an einem langperiodischen transportablen Vertikalseismographen gebaut, der zur Untersuchung der seismischen Bodenunruhe dienen soll. Nach Fertigstellung des Versuchsinstrumentes sollen 6 Geräte desselben Types hergestellt werden, um 2 Tripartitestations ausrüsten zu können. Ebenfalls für die Zwecke der Untersuchung der seismischen Bodenunruhe sollen die Mainkaseismographen der früheren Hamburger Erdbebenstation dienen. Zu diesem Zweck werden sie auf eine Periode von etwa 30 sec und optische Registrierung umgestellt.

Im August 1953 wurden auf Sylt Untersuchungen der kurzperiodischen Bodenunruhe durchgeführt. Diese Messungen werden noch weitergeführt werden. Mit einem abschließenden Bericht darüber kann man im Jahre 1954 rechnen. Gelegentlich wurden in der Berichtszeit Messungen von Industrieerschütterungen durchgeführt.

Untersuchungen über die seismische Bodenunruhe (H. Menzel, H. Westerhausen), über ortsgültige Laufzeitkurven von P und S für Hamburg (K. Strobach) und über die Fortpflanzung seismischer Wellen in einem festen Körper mit elastischer Nachwirkung (H. Menzel) befinden sich im Druck. Zwei weitere Untersuchungen über das Problem des Abweichens des Materials der Erdkruste vom ideal- elastischen Verhalten sind in Angriff genommen.

3) *Heidelberg.* Erdbebenwarte auf dem Königstuhl. — Der Betrieb mit dem Wiechertschen Horizontalseismographen mußte im Winter 1951/52 eingestellt werden. Die Station hat sich nun dem von Stuttgart aus unterhaltenen Stationsnetz angeschlossen. Geplant ist

die Aufstellung eines vollständigen Satzes der Nahbeben-Seismographen, Bauart «Stuttgart», mit mechanischer Registrierung, sobald die dazu erforderlichen Instrumentenräume ausgebaut sind.

4) *Karlsruhe.* Erdbebenwarte am Geodätischen Institut der Technischen Hochschule. Die beiden großen Horizontalpendel mit 2000 kg Pendelmasse und der Wiechert'sche Vertikal-Seismograph mit 1300 kg Pendelmasse waren fast ohne Unterbrechung in Betrieb. Die Registrierapparate erhielten Laufwerke mit elektrischem Aufzug, die an der Feintechnikschule in Schwenningen angefertigt wurden. Für die Registrierung von Nahbeben wurden zwei Horizontal-Komponenten in einer ihren Zwecken entsprechenden Eigenperiode und Vergrößerung neu aufgestellt. Geplant ist ein Umbau des Vertikalseismographen zur Erreichung einer stärkeren Vergrößerung und die Anlage einer neuen Berußungsvorrichtung.

Die Ergebnisse der Registrierungen werden regelmäßig in Halbjahresberichten den in- und ausländischen Stationen zugestellt. Von Karlsruhe aus wird auch das ehemalige Land Baden weiter makroseismisch betreut.

5) *Kleiner Feldberg.* Die auf dem Kl. Feldberg im Taunus befindliche Erdbebenstation ist dem Institut für Meteorologie und Geophysik der Universität Frankfurt a/Main angegliedert (Leitung: Prof. Dr. R. Mügge). Sie verfügt zur Zeit über zwei Horizontalseismographen nach Mainka. Seit einem Jahr wird auch die Möglichkeit verfolgt, mit Hilfe der Schwankungen des Grundwasserstandes am Westrand des Vogelsbergs (Wasserwerk Inheiden) Fernbeben zu registrieren. Es hat sich gezeigt, dass mittels eines Schwimmpegels auf dem dort in Klüften anstehenden Grundwasser lesbare Seismogramme gewonnen werden können. (Siehe die Aufsätze von *Junge* in der « Umschau » 1952, Heft 7 und von *R. Mügge* in der Zeitschrift der Senkenbergischen Naturforschenden Gesellschaft « Natur und Volk » 1953, Heft 7.)

6) *München.* Der Erdbebendienst wird vom Institut für angewandte Geophysik der Universität (Leitung : Prof. Dr. H. Reich) wahrgenommen. Da die alte Erdbebenwarte auf dem Gelände der Sternwarte im Kriege zerstört wurde und ein Wiederaufbau an derselben Stelle wegen des starken Verkehrs innerhalb der Stadt keinen Sinn hat, ist die Wiedererrichtung der Erdbebenwarte auf dem Gelände der Erdphysikalischen Warte und des Erdmagnetischen Observatoriums in Fürstenfeldbruck, 20 km westlich von München, in Aussicht genommen. Doch war es noch nicht möglich, die erforderlichen Geldmittel für die Errichtung der Gebäude zu erhalten.

Es war jedoch in den letzten beiden Jahren möglich gewesen, das wesentliche Instrumentarium für die Erdbebenwarte, so wie sie zunächst geplant ist, zu erwerben. Die Feintechnikschule in Schwenningen/Neckar lieferte einen vollständigen Satz Seismographen, System Stuttgart, für Nahbebenregistrierungen mit Zubehör. Von der Fa. Clemens Riefler, Nesselwang, konnte eine Uhrenanlage, wie sie bei anderen Erdbebenwarten zur Zufriedenheit schon benutzt wird, beschafft werden. Für die Registrierungen von Fernbeben steht der astatische Wiechert-Horizontalseismograph von der alten Erdbebenwarte zur Verfügung. Er bedarf nur einer generellen Ueberholung.

Sobald die Gebäude in Fürstenfeldbruck errichtet worden sind, was aller Voraussicht nach bald geschehen wird, kann die neue Erdbebenwarte ihre Tätigkeit aufnehmen.

Von wissenschaftlichen Arbeiten ist zunächst die Untersuchung des Aufbaus der Erdkruste auf Grund der Großsprengungen auf Helgoland (1947) und Haslach im Schwarzwald (1948) durch H. Reich, O. Förtsch und H. A. Schulze zu nennen. H. Reich diskutierte überdies auch nach Steinbruchsprengungen in Blaubeuren, in Unterfranken und im Raum von der Donau bis zu den Alpen mittels Reflexions- und Refraktionsbeobachtungen die Beschaffenheit des tieferen Untergrundes der betreffenden Gebiete. Ferner hat O. Förtsch in Fortsetzung einer Untersuchung von Rössiger den ausschlaggebenden Einfluß von Blattfedern auf das Verhalten von Blattfederseismographen theoretisch und experimentell aufgezeigt und Untersuchungen von Oberflächenwellen, welche durch Maschinen und Sprengungen angeregt worden sind, angestellt.

7) *Münster.* Die dem Geologischen Institut der Universität (Leitung: Prof. Dr. Fr. Lotze) angegliederte Erdbebenstation (Leitung: Dr. B. Brockamp) ist seit Dezember 1953 in Betrieb. Sie ist ausgerüstet mit einem Satz Hillerscher Seismographen (Eigenperiode 1.4 sec). Da die Aufstellung zunächst im Institutsgebäude erfolgt ist, mußte eine 1500fache Vergrößerung genügen.

8) *Rheinland.* Vom Geologischen Institut der Universität Köln (Leitung: Prof. Dr. M. Schwarzbach) ist die Errichtung von zwei Erdbebenstationen in Angriff genommen worden: eine Hauptstation in Bensberg bei Köln und eine Außenstation in Mechernich in der Nordeifel.

a) *Bensberg.* Ein kleines Stationsgebäude konnte im Herbst 1953 fertiggestellt werden. An instrumenteller Ausrüstung ist vorgesehen: Für alle drei Komponenten je ein kurzperiodischer Seismograph Hillerscher Bauart (Eigenperiode 1,4 sec, maximale Vergrößerung für Perioden von rd. 1 sec 7000, galvanometrische Registrierung) und außerdem ein von der ehemaligen Erdbebenwarte in Jugenheim a.d.B. übernommener und umgebauter Horizontalseismograph nach Wiechert (Masse 1300 kg). Mit dem Einbau der Instrumente soll im Frühjahr 1954 begonnen werden.

b) *Mechernich.* Hier wurde 1953 versuchsweise für die E-W-Komponente ein Horizontalpendel mit Dämpfung und Rußschreibung nach Hiller-Schulz im Dienstgebäude der Gewerkschaft Mechernicher Werke aufgestellt (Masse 130 kg, Eigenperiode 4 sec, Vergrößerung 90, Registriergeschwindigkeit 30 mm/min).

9) *Württembergischer Erdbebendienst* (Leitung: Prof. Dr. W. Hiller).

a) *Stuttgart* (Hauptstation). Zusätzlich zu den im letzten Bericht aufgeführten Instrumenten wurde im Herbst 1951 ein homogener Satz Nahbeben-Seismographen der Bauart «Stuttgart» mit galvanometrisch-optischer Registrierung und mit einer Registriergeschwindigkeit von 60 mm/min in Betrieb genommen. Um die Rück-

wirkung des Galvanometers auf den ursprünglich ohne zusätzliche Pendelmasse angefertigten Pendelarm zu verringern, wurde im Sommer 1953 an dem Pendelarm nahe der Pendelachse noch eine zusätzliche Masse von 1 kg angebracht. Mit den neuen hochwertigen Alnico-Legierungen für die Dämpfermagnete ist trotzdem aperiodische Dämpfung leicht möglich. Das Anbringen dieser zusätzlichen Pendelmasse hatte eine Verkleinerung der reduzierten Pendellänge auf nahezu die Hälfte zur Folge, wodurch die maximale Vergrößerung dieser Seismographen auf rund 15.000 gesteigert werden konnte. Eine weitere Steigerung der Vergrößerung ist bei der Aufstellung in Stuttgart wegen der Stadtunruhe nicht angezeigt.

Seit dem Winter 1952/53 sind Versuche im Gange, um für diese Seismographen einen geeigneten, einfach und betriebssicher gebauten Verstärker zu erproben, mit dem es möglich werden soll, die kostspielige optische Registrierung durch eine mechanische Registrierung auf Rußpapier zu ersetzen. Diese Umstellung geschieht vor allem im Hinblick auf die geplante Aufstellung dieser Seismographen an den Außenstationen Ravensburg, Heidelberg, Meßstetten und Tübingen. Die dazu erforderlichen Registrierapparate mit 60 und 120 mm/min. Registriergeschwindigkeit werden gegenwärtig an der Feintechnikschule in Schwenningen/N gebaut. Im allgemeinen werden sie mit 60 mm/min laufen; in Meßstetten, das ganz nahe am Herdgebiet der Schwäbischen Alb liegt, werden sie aber teilweise mit 120 mm/min laufen müssen, um noch eine genügende Auflösung der Seismogramme zu geben.

Seit September 1953 werden in Stuttgart die Zeitsignale unmittelbar auf den Nahbeben-Seismographen mit 60 mm/min Registriergeschwindigkeit mitregistriert, sodass eine Auswertung der Seismogramme mit der gewünschten Zeitgenauigkeit von 1/10 sec möglich ist. Aehnliche Vorrichtungen sollen auch an den Außenstationen eingebaut werden.

Im Sommer 1952 wurde ein weiterer großer Instrumentenraum mit zwei Betonsockeln ausgebaut, der in erster Linie experimentellen Arbeiten dient.

Im Laufe der Jahre 1952 und 1953 wurden an der Feintechnikschule in Schwenningen vollständige Sätze der Nahbeben-Seismographen, Bauart « Stuttgart », mit galvanometrisch-optischer Registrierung für die Erdbebenstationen in Köln, Münster i. Westf., Wien und München gebaut. Dieselben Seismographen, die aber auf mechanische Registrierung umgestellt werden sollen, sind für Ravensburg, Meßstetten und Heidelberg im großen und ganzen ebenfalls fertiggestellt.

Die Auswertungen der Seismogramme von Stuttgart, Ravensburg und Meßstetten werden in vorläufigen Berichten alle 10 Tage an eine kleine Anzahl von Stationen und jeden Monat an 70 Stationen verschickt. Die endgültigen Jahresberichte erhalten rund 200 Stationen. Stuttgart besorgt weiter die makroseismische Ueberwachung der früheren Länder Württemberg und Hohenzollern.

Im Oktober 1953 reiste Herr Dr. R. Schulz, der mehrere Jahre an der Stuttgarter Hauptstation tätig war, nach San Salvador; er wurde vom Instituto Tropical de Investigaciones Cientificas in San Salvador beauftragt, dort einen neuzeitlichen Erdbebendienst einzurichten.

b) *Ravensburg.* Die vorhandenen Instrumente waren ohne Aenderung dauernd in Betrieb.

c) *Meßstetten.* Auch hier waren die drei Seismographen ohne Aenderung dauernd in Betrieb. Da der seitherige Instrumentenraum verhältnismäßig klein und die Aufstellung weiterer Instrumente in diesem Raum nicht möglich ist, wurde im Frühjahr 1953 die Gelegenheit benützt, in dem sehr günstig gelegenen Neubau einer Turn- und Festhalle der Gemeinde Meßstetten zwei geeignete und genügend grosse Räume für die Erdbebenstation anzubauen. Der Umzug in diese Räume ist für den Sommer 1954 vorgesehen.

d) *Tübingen.* Der laufende Stationsbetrieb ist immer noch unterbrochen.

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Vorangestellt sei der Hinweis auf die sechste Auflage des « Landolt-Börnstein » (Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik). Als III. Band, herausgegeben von J. Bartels und P. ten Bruggencate, erschien 1952 « Astronomie und Geophysik ». Hier wurden im Abschnitt 324 (« Erdkörper ») die Fragen « Seismizität der Erde », « Erdbebenwellen », « Erdinneres » und « Gezeiten des Erdkörpers» von E. C. Bullard, B. Gutenberg, H. Lettau und E. Tams behandelt. Ferner erschien 1953 von K. Jung die « Kleine Erdbebenkunde » in der Sammlung « Verständliche Wissenschaft » in zweiter Auflage.

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Erstattet von Professor Dr. *E. Tams*, Hamburg.

REPUBLIQUE ARGENTINE

REPORT ON SEISMOLOGICAL WORK IN ARGENTINA

1951 TO 1954

I. — *Servicio Meteorológico Nacional*

Period covered by this report : March 1, 1951 to March 1, 1954.

a) Field work. A new earthquake-station was installed at Bosque Alegre, Provincia de Córdoba, in 1951. This observatory is located in a vault directly cut into the slope of a mountain-side of rocky constitution. Access to the vault is through a tunnel of 33 meters length; the construction is a single concrete block.

Main data of the new station :

Equipment : One Wiechert type horizontal two-component seismograph, of 200 kilos; one pendulum chronometer for time marks.

Coordinates :

Latitude : 31° 34' 54" South

Longitude : 64° 32' 45" West.

Ground : Palaeozoic metamorphized rock (gneiss).

Yearly routine inspections were made at the observatories of the

network, to maintain the equipment and determine instrument constants. Geotectonic surveys were carried out in the surroundings of Salto Grande (Provincia de Entre Rios), and also in the Province of Mendoza. Furthermore, vibrometric field studies were made at the following official departments :

1) Municipal Building Department (Dirección General de Obras Municipales de Buenos Aires);
2) Workshop of the General Belgrano Railway;
3) Hydrographic Service (Dirección General de Navegación e Hidrografía, del Ministerio de Marina).

b) Observatory network. The following network of stations is in permanent operation :

Buenos Aires, Mendoza, Tucumán, Bosque Alegre, Isla Decepción (Antártida Argentina); 295 earthquakes were recorded and read with epicentres inside and outside the country; the recordings were processed in accordance with the directions given in the handbook by Frank Neumann.

A ten-daily seismological information bulletin is issued and interchanged with national and foreign institutions. The more important earthquakes of focal distance under 5000 km were reported by telegram to the U.S. Coast and Geodetic Survey, with the aid of the 1948 code. General information on earthquakes is released to news agencies for distribution to newspapers and broadcasting stations. Compilation and processing of former seismological data for statistical purposes is being continued. The network of macroseismic observers and correspondents is being maintained as in former years, and attempts are made to extend it wherever this is possible. A stereographic projection map was drawn to facilitate determination of epicentres.

c) Instruments. A new one second contact pendulum was designed and built in the workshop of the S.M.N.; this chronometer is being used with very satisfactory performance at one of the observatories. The design of the «Modelo Argentino» seismograph was analysed with regard to smoothness of functioning, and slight design changes were introduced.

d) Publications.

1) Anales Sismológicos, Años 1948-49-50, Observatorio Central Buenos Aires; Publicación de la Dirección General del Servicio Meteorológico Nacional; Serie B; 2a. Sección, 4a. Parte, nº 1, Buenos Aires, 1952.
2) Idem año 1951, Observatorio Central Buenos Aires; Publicación de la Dirección General del Servicio Meteorológico Nacional; Serie B; 2a. Sección, 4a. Parte, nº 2, Buenos Aires, 1953.
3) Raimundo Celeste. — Contribución al conocimiento sísmico de la Provincia de Mendoza; en «Meteoros»; año II, nº 3-4, pág. 166-182.
4) Raimundo Celeste. — Reconocimiento geotectónico en las inmediaciones de Salto Grande (Entre Ríos); en «Meteoros»; año I, nº 2-3, pág. 183-189.

5) Raimundo Celeste. — Contribución al conocimiento sísmico de la Provincia de Salta; en «Meteoros»; año II, nº 1-2, pág. 101-112.

II. — *Observatorio de la Universidad Nacional Ciudad Eva Perón*

The seismological service was maintained without interruption, and a total number of 590 earthquakes were recorded between January 1951 and January 1954. Monthly seismological bulletins covering the years 1949 and 1950 were released. A summarized seismological bulletin comprising the main phenomena recorded in 1953 was made up and was sent to the I.S.S., to the Bureau Central Séismologique of the U.G.G.I., and to the Seismological Committee of the Panamerican Institute of History and Geography. The following theoretical papers were published by Ing. Gershanik :

1) Contribución al estudio de cargas sísmicas sobre edificios; (Serie Geofísica VIII, 1).
2) Contribución a la teoría de los sismógrafos mecánicos; (Serie idem, VIII, 2).
3) Algunos recursos para adaptar curvas de tiempos de recorrido a distintas profundidades hipocentrales (Memoria del 1er. Congreso Nacional de Cartografía en la Argentina).

Moreover, the same author prepared the following notices, to be published in the future :

4) Sugestiones para determinar la amplificación en los sismógrafos; (to be published in: Memoria del 2do. Congreso de Cartografía de la Argentina).
5) Mejoras en la apreciación de cargas sísmicas sobre edificios; (to be published as: tomo VIII, 3 de la Serie Geofísica del Observatorio).

AUSTRALIE

REPORT ON SEISMOLOGY IN AUSTRALIA, 1951-1953

Observatories and Instruments.

Adelaide. The Adelaide Observatory has been closed. The Milne-Shaw Seismograph, formerly operated by this Observatory, has been taken over by the Department of Physics, Adelaide University, and, having been overhauled, is in continuous operation; but no bulletins are issued. It is proposed to begin a course in Geophysics in 1955, when it is hoped that more use may be made of the seismograms and, if interest in the course warrents the expense, other instruments may be installed.

Brisbane. Seismological Station, Department of Geology, University of Queensland.

Instruments : a) Benioff Variable Reluctance Vertical, with two coils, one operating a galvanometer of period 0.25 sec. the other a galvanometer of period 23 sec. Recording on 35 mm film.

b) Two modified Milne-Shaw Seismographs, of period 12 sec.

c) Three long period (7 sec.) Sprengnether Horizontal Seismographs, recording on a single drum. These are used mainly for microseismic work.

d) Sprengnether long period (7 sec.) Demonstration model, recording with pen and ink.

e) Kew Type short period Vertical (0.8 sec.).

f) Two Wood-Anderson short period (1.0 sec.)

Daily telegrams are sent to the U.S.C.G.S.; weekly bulletins to a selected number of stations in the S-W Pacific Region; monthly bulletins sent throughout the world.

Research includes investigations into local tremors and microseismic research, focussed mainly, but not exclusively upon the relation of microseisms to cyclones.

Perth Observatory.

Instruments : a) Milne-Shaw N-S.

b) Long period vertical and matched microbarograph, on loan from the Lamont Geological Observatory of Columbia University (New York), for use in connection with a research programme initiated by the Lamont Observatory.

A quarterly bulletin is issued and sent to 58 stations; no other seismological investigations are undertaken.

Riverview College Observatory (Sydney).

Instruments : a) Mainka N-S & E-W, Period, 10 sec.

b) Wiechert, N-S, E-W (period 7 sec.); Vertical period 5 sec.

c) Galitzin, N-S, E-W & Vertical. Period 10 sec.

d) Sprengnether Vertical, Period 1.6 sec.

Preliminary bulletin sent monthly to selected stations, annual bulletin to all stations. Details of larger shocks cabled to the U.S.C.G.S.

Recent research includes investigation into the direction of motion of First Impulses; the T-phase from the New Zealand Region; a continued search for evidence of the phase PKJKP; collection of data for an investigation of the ground motion as determined from various types of instrument.

Bureau of Mineral Resources, Geology and Geophysics.

The Bureau of Mineral Resources, with headquarters in Melbourne, maintains stations in Melbourne, Heard Island and Macquarie Island. The instruments in use are :

I) Melbourne : Milne-Shaw, E-W, Period 12 sec.

II) Heard Island : a) Wood-Anderson, N-S, E-W, Period 0.75 sec. before February, 1954; 9 sec. after that date.

b) Grenet Vertical. Period 1.3 sec.

III) Macquarie Island : Wood-Anderson, N-S, E-W. Period 1 sec.

Two special investigations were undertaken during the period 1951-1953 :

A. Following the explosive eruption of Mount Lamington (New Guinea) in January 1951, a seismological observing station was set up at Popondetta at a distance of 7.8 miles due north of the crater. The instruments used were :

Wood-Anderson, N-S, E-W, Period 0.8 sec.
Geophone (exploration type) Vertical Component. Period 0.5 sec.
Sensitive Level, N-S direction.

Recording was carried out continuously from 5th February, 1951, to 31st July, 1952. Tremors, associated with activity in the crater, were recorded throughout the whole of this time with varying magnitude and frequency. There were periodic rises and falls in the average level of activity with a general decrease over the period of observation. A preliminary analysis suggests that there may be a gradual increase in seismic activity during the period preceding an eruption, with a marked lull in seismic activity just before the event. The average individual tremor recorded had an energy of about 2×10^{17} ergs. A full analysis of the results is in the course of preparation.

B. At the time of the atomic bomb explosion on the Woomera Rocket Range in October, 1953, observations were made with a view to determining something of the crustal structure of Central Australia. Seismic observation points were set up at distances ranging from about 5 to 300 kilometres from the firing point. Records of both surface and body waves were obtained at five stations. A preliminary analysis indicates that both granitic and intermediate layers are present with a total depth of about 53 kilometres to the Mohorovicic discontinuity. The results have not yet been released for publication.
The general field seismic investigations carried out fall into two main categories :

a) Shallow refraction profiling.
Surveys are made by this method, particularly in the mountainous country of New South Wales and Tasmania, to determine near-surface geological structure. This information is required when choice has to be made of sites for dams, tunnels, power stations, etc.

b) Deep refraction and reflection seismic surveys.
These investigations are made in the search for geological structures of economic importance. Several such surveys have been carried out in Victoria, Queensland and Western Australia, usually in conjunction with gravity measurements. Signi-

ficant contributions have been made to the knowledge of the sub-surface geology of these regions.

Future Research.

As part of the general programme of research, the Bureau is establishing stations at several points throughout Australia and its dependencies. It is expected that within the next two years stations will have been set up in Perth (Western Australia), Mawson (Antarctica) and Port Moresby (New Guinea). These, in conjunction with existing stations will provide data on : i) the seismicity of the Australian Region, ii) crustal structure of this and adjacent zones, iii) microseismic activity.
The Bureau has also carried out work that has relation to the Physics of the Interior of the Earth. The main phases of this work are :

a) Network of absolute pendulum stations.
The Bureau has established 60 pendulum stations in Australia using two sets of three invar gravity pendulums of the van Sterneck type. These are on loan from the Department of Geology and Geodesy of Cambridge University. The Australian network is tied through Cambridge and Teddington to the Potsdam System. The results are being analysed in the light of the various hypotheses of Airy, Heiskanen and Hayford. Investigation is still in progress. There are several notable anomalies that appear to be related to major geological features

b) Regional gravimeter surveys.
Such surveys have been carried out over several large areas. Chief amongst them are :

I. The West coast of Western Australia, from Albany to Oslow, over a width of from 50 to 150 miles. Observations were made at intervals of 5 to 10 miles along traverses spaced some 20 to 60 miles apart. An area of 95,000 square miles has been covered with 1,400 stations. The results indicate a very marked gravity minimum along the western side of the Darling escarpment, with a lowest value of-140 milligals in the vicinity of Watheroo. This suggests the existence of a major rift valley running parallel to the edge of the Continent, from Cape Leeuwin to Geraldton. The magnitude of the anomaly may represent a thickness of at least 20,000 feet of sediments. Some deep-seated discontinuity in the crust probably contributes to the total gravity anomaly.

II. The Gippsland area of Victoria. This has been covered by 6,500 stations over an area of 6,500 square miles. The purpose of this survey was to determine structures favourable to the deposition of brown coal (lignite) and oil.

III. Other areas covered in the same way are the Kimberleys District of Western Australia (8,300 sq. m., 1,300 stations), Western Victoria (2,600 sq. m., 650 stations), Roma District, Queensland (2,000 sq. m., 750 stations) and the Oaklands District of New South Wales (1,500 sq. m., 400 stations).

The Sub-Committee on Seismology of the Australian National Committee of Geodesy and Geophysics consists of the following members :

Prof. K. E. Bullen, F.R.S.,
Fr. T. N. Burke-Gaffney, S. J. Secretary,
Dr. O. A. Jones,
Dr. F. W. Wood.

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T. N. BURKE-GAFFNEY.

AUTRICHE

TÆTIGKEITSBERICHT

1) Seismische Observatorien.

a) *Wien, Hohe Warte.* $\lambda = 16° 21' 7$ E, $\varphi = 48° 14' 9$ N, h = 198 m.
Ausrüstung : Wiechert-Horizontal 1000 kg,
Wiechert-Vertikal 1300 kg,
Conrad-Pendel 24 kg, für Nahbeben.

b) *Graz, Physik. Institut.* $\lambda = 15° 26' 9$ E, $\varphi = 47° 04' 6$ N, h = 369 m.
Ausrüstung : Wiechert-Horizontal 1000 kg.
Wegen baulicher Umgestaltung des Instituts derzeit nicht in Betrieb.

c) *Kremsmünster, Stiftssternwarte.* $\lambda = 14° 06' 7$ E, $\varphi = 48° 03'4$ N, h = 383 m.
Ausrüstung : Nahbebenpendel 100 kg.
Derzeit noch im Zustand der Erprobung.

Bemerkung : Derzeit werden nur die Beobachtungen von Wien veröffentlicht (Seismische Aufzeichnungen von Wien ab 1952). Es ist beabsichtigt, das Netz der Nahbebenstationen durch Aufstellung zweier Pendel in *Bleiberg* (Kärnten) und *Innsbruck* (Tirol) zu erweitern und dadurch Registriermöglichkeiten in der nächsten Umgebung aller seismischen Aktionszentren zu haben. Ebenso wird in nächster Zeit im Bereich des erdmagnetischen Observatoriums Wien—Kobenzl ein homogener Satz galvanometrisch registrierender Pendel, Bauart «Stuttgart», aufgestellt und damit auch die Reichweite des Wiener Observatoriums bedeutend vergrössert werden.

2) Die Bearbeitung der nicht sehr häufigen und meist recht schwachen makroseismischen Erscheinungen enthalten die jährlich im *Jahrbuch der Zentralanstalt für Meteorologie und Geodynamik* erscheinenden « Makroseismischen Beobachtungen », die auch die Fortführung des Bebenkataloges darstellen.

3) Für die Ausgestaltung des landeseigenen Netzes an mikroseismischen Stationen war die Entwicklung eines hinreichend empfindlichen, aber einfachen und billigen Pendels notwendig. Dazu wurde das leichte Conrad-Pendel vergrössert und in seiner Leistung und Justierbarkeit verbessert. Das neue Pendel ist ein Rußschreiber mit einer stabilen Pendelmasse von 100 kg, die mit einem labilen, kleinen Pendel gekoppelt ist. Es hat ein elektrisches Laufwerk mit einem Papiertransport von 20 mm Papier = 1 Minute. Die normalen Betriebsdaten, die leicht eingehalten und eingestellt werden können, sind $V = 40$, $T_0 = 6$ sec. Das Pendel hat Oeldämpfung.

4) *Bibliographie.*

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Mikroseismische Beobachtungen 1951, 1952, 1953, beide erscheinen im jeweiligen *Jahrbuch der Zentralanstalt für Meteorologie und Geodynamik,* Wien.

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M. TOPERCZER.

BELGIQUE

LA SEISMOLOGIE EN BELGIQUE DE 1951 A 1953

La *Station séismologique de l'Observatoire royal de Belgique,* telle qu'elle fut présentée à l'Assemblée de Bruxelles en 1951, n'a pu entrer réellement en service qu'au cours de 1952. Il a fallu, en effet, dégager la cave pour la recouvrir d'une couche de béton cellulaire fixée au bitume pour parer aux infiltrations d'eau. Ces travaux ont été effectués au début de l'année, tandis qu'il était procédé dans les locaux à l'achèvement des tableaux de connexions électriques.

De l'équipement de la Station, décrit par M. Ch. Charlier dans le rapport triennal précédent, seule la cabine de télécontrôle n'a pas encore été mise en service. Les séismographes galvanométriques fonctionnent comme indicateurs de phases, les circuits galvanométriques n'ayant pu jusqu'ici être compensés.

Malgré cet état de choses, il a été possible, après une interruption de 4 ans, de reprendre la publication du « Bulletin séismique provisoire » (bimensuel) au 1er janvier 1953. Le dépouillement des séismogrammes et la rédaction du bulletin sont assurés par M. J. M. Van Gils qui a succédé à M. Ch. Charlier à la tête du Service séismologique de l'Observatoire Royal de Belgique. Le « Bulletin séismique provisoire » est transmis à 80 stations étrangères. Le « Bulletin séismique annuel 1953 » sera publié par fascicules dans le courant de

l'année 1954. Ce mode de publication a été adopté en vue d'accélérer la distribution du bulletin définitif.

Au Centre de Physique du Globe de l'Institut Royal Météorologique à Dourbes sera installée fin 1954, une station séismologique desservie par l'Observatoire Royal de Belgique. Sont prévus : 3 séismographes Sprengnether, dont un vertical à courte période et 2 horizontaux type H, ainsi que 3 séismographes de l'Institut Royal Météorologique (1 vertical et 2 horizontaux - construction Askania) à courtes périodes qui seront utilisés également pour l'étude des microséismes à très courtes périodes en liaison avec les variations microbarométriques.

Pendant l'année 1953, il a été enregistré à Uccle 480 séismes mondiaux et locaux. Parmi ceux-ci 8 secousses principales ont affecté le sol belge, à savoir :

1) le 6 janvier 1953 : épicentre macroséismique : 50°37'N — 4°36'E. $\triangle$ = 25 km. — H = 23.58:44.
   Intensité maximum VI (Echelle Mercalli-Sieberg). Ce séisme a été suivi d'une vingtaine de répliques non enregistrées.
2) le 28 janvier 1953 : réplique du précédent. H = 13.43:06 — Intensité maximum III.
3) le 6 février 1953 : réplique du 1) — H = 11.58:48 — Intensité maximum III.
4) le 11 juin 1953 : secousse ressentie à Boussoit (Hainaut) — $\triangle$ = 50 km. — Epicentre macroséismique : 50°,5 N — 4°,1 E — Intensité maximum II-III, aire séismique réduite à la commune.
5) le 28 août 1953 : même épicentre que le 6 janvier — Intensité maximum VI — H = 00.05:21.
6) le 28 août 1953 : même épicentre que le 6 janvier — Intensité maximum VI — H = 00.06:16.
7) le 30 août 1953 : séisme dans le S.-E. de la province de Liège — $\triangle$ = 1°,1 = 120 km — H = 23.35:30 — Intensité maximum VI — Epicentre macroséismique : 50°,4 N — 5°,9 E.
8) le 15 septembre 1953 : secousse aux confins des communes Baudour et Quaregnon (Hainaut). Aire pléistoséiste comprise dans un rayon de 100 m autour de l'épicentre macroséismique : 50°27' N — 3°51' E. — $\triangle$ = 55 km. — H = 23.55.00 — Intensité max. VII.

Outre ces 8 secousses, il a été ressenti en Belgique, entre janvier 1951 et le 31 décembre 1952:

1) le 14 mars 1951: le séisme de Rhénanie (Euskirchen). L'enquête couvre tout le territoire (pas d'enregistrements). — Intensité maximum observée : VI.
2) le 7 septembre 1951: le séisme de Theux (enregistré) — Epicentre macroséismique : 50°32' N — 5°50' E. — $\triangle$ = 115 km. — Intensité maximum VI. — Ressenti sur une grande partie du territoire.
3) le 9 avril 1952 : la secousse de La Louvière (Hainaut) à 21 h. 35 m. Aire séismique réduite à la commune — Intensité maximum observée : III-IV.
4) le 21 octobre 1952 : le séisme du Couchant de Mons à 21 h. 15 m. — Aire séismique étendue à une vingtaine de communes — Intensité maximum observée : IV.

5) le 22 octobre 1952 : réplique du précédent — Intensité maximum IV.

6) le 27 octobre 1952 : secousse à 6 h. 11 m. — Intensité maximum VI — Même épicentre que le 21 octobre 1952.

Pour chacune de ces secousses, des visites sur place et des enquêtes macroséismiques ont été effectuées.

En août 1953, des mesures du déplacement du sol provoqué par le passage de trains ont été faites le long de la voie ferrée pour le Service de la Voie de la Société Nationale des Chemins de Fer Belges.

Sur le plan international, M. Ch. Charlier a participé aux travaux de la Commission Séismologique européenne, réunie à Stuttgart du 23 au 28 septembre 1952 et y a présenté une note concernant « Les secousses séismiques en 1951 et la Structure de l'Ecorce terrestre en Belgique ».

Son décès, survenu après une longue et pénible maladie, prive la Belgique d'un séismologue de classe. Ses collègues belges conservent de cet homme courtois, un souvenir ému.

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P. BOURGEOIS,

Directeur de l'Observatoire Royal de Belgique.

CANADA

Voir le Rapport National en Annexe à la fin du volume.

COLOMBIE

INFORME NACIONAL SOBRE LA ACTIVIDAD DE LA SISMOLOGIA EN LA REPUBLICA DE COLOMBIA PARA EL PERIODO 1951-1953

En el territorio de la República de Colombia, Sur América, funcionan actualmente tres estaciones sismologicas de primera clase, a saber. *Bogotá, Galerazamba* y *Chinchiná.*

La primera por su antigüedad e importancia es la estación central del Instituto Geofísico de los Andes Colombianos en Bogotá, Latitud 4° 37' 23" Norte, Longitud 74° 03' 54" O. Greenwich. Está emplazada en una arenisca del terciario.

Esta estación funcionó primeramente en el centro de la ciudad en el antíguo Colegio de San Bartolomé con un Wiechert horizontal de 200 kilos de la casa Spindel Hoyer de Göttingen y un Cartuja horizontal construído en Granada, España e introducidos a Colombia en 1923. El 27 de Septiembre de 1941 se fundó la nueva estación sismológica de Bogotá al inaugurarse por los Jesuítas el Instituto Geofísico de los Andes Colombianos en el nuevo Colegio de San Bartolomé-La Merced, al pie de uno de los cerros orientales de la ciudad. El instrumental de la nueva estación consiste en :

2 — Componentes horizontales Sprengnether período de 16 segundos.

1 — Componente vertical Benioff, período corto (0.3 seg.).

1 — Wiechert horizontal de dos componentes.

1 — Acelerógrafo tipo Montana, instalado en 1945 por el U. S. Coast and Geodetic Survey.

1 — Reloj patrón de la Standard Time Co.

1 — Radio Receptor Hallicrafters SX-42, para recibir y marcar las señales horarias.

1 — Alarma electrónica Sísmica.

1 — Radio Transmisor Johnson Viking I para la comunicación radio-telefónica con las otras estaciones sismológicas colombianas.

1 — Aparato de aire acondicionado de la Curtis Manufacturing Co.

Esta estación está dirigida por el P. Jesús Emilio Ramírez, S. J.

La estación sismológica de Galerazamba, a 21 metros sobre el nivel del mar y a 65 kilómetros de Cartagena en el mar Caribe, fue inaugurada el 27 de Enero de 1950.

Latitud 10° 47' 03" Norte.

Longitud 75° 15' 44" Oeste de Greenwich.

Esta estación está auspiciada por la Sección Salinas del Banco de la República.

La bóveda sísmica especialmente diseñada con aire acondicionado descansa sobre arcilla oligocena. Su instrumental consta de :

2 — Componentes horizontales Sprengnether de período de 16 seg.

1 — Componente vertical Sprengnether de período corto.

1 — Reloj patrón de la Standard Time Co.

1 — Radio Receptor Hallicrafters SX-42.

1 — Radio Transmisor.

La tercera estación sismológica de Chinchiná, inaugurada el 22 de Julio de 1950 tiene las siguientes coordenadas geográficas :

Latitud 4° 58' Norte.

Longitud 75° 37' Oeste de Greenwich.

El carácter del subsuelo es de aluvión rocoso.

El equipo es exactamente igual al que posee la estación sismológica de Galerazamba y su fundación y sostenimiento ha sido patrocinado por la Federación Nacional de Cafeteros.

Estas tres estaciones sísmicas trabajan armónicamente y gozan de un intercambio diario de mensajes sísmicos por medio de radiofonía directa, enlace radiofónico que está dando excelentes resultados en un país en donde las distancias, la bravía topográfica del terreno y las condiciones especiales de servicios, causan retardos en comunicaciones que requieren un intercambio rápido de información.

El Instituto Geofísico de los Andes Colombianos en Bogotá en cooperación con el Instituto Geográfico de Colombia « Agustín Codazzi », es la entidad oficial en Colombia para asuntos sismológicos y es la encargada de recibir y archivar los registros fotográficos de las 3 estaciones sismológicas colombianas, de interpretar las fases de los sismos, publicar los boletines y dar las informaciones.

Los cuestionarios sísmicos impresos por el Instituto Geográfico de Colombia « Agustín Codazzi », se han enviado a los Señores Alcaldes y curas párrocos de las regiones afectadas después de cada sismo de alguna importancia en Colombia. Señaladamente se han estudiado así en los últimos 2 años los sismos colombianos de Murindó, en los límites de los Departamentos de Antioquia y Chocó, (Febrero 14 de 1952), de Guachetá, Departamento de Cundinamarca (Julio 7 de 1953) y el de Túquerres, Departamento de Nariño (Diciembre 22 de 1953).

Los Boletines Sísmicos se publican mensualmente en mimeógrafo abarcando varios meses cada vez, los que se distribuyen mundialmente, también se envían Boletines Preliminares por correo aéreo a los centros sismológicos, y por cable los datos de los terremotos de mayor interés al U. S. Coast and Geodetic Survey de Washington.

Algunos sismos colombianos como el de Arboledas en Colombia (Julio 9, 1950) han servido notablemente para que los ingenieros y

las sociedades constructoras examinen detenidamente los métodos de construcción de viviendas con el fin de hacerlas antisísmicas. En las regiones sísmicas son ya varios los centenares de casas construídas con columnas de armadura metalica empotradas en los cimientos reforzados, formando con las cerchas una verdadera osatura rígida.

El recto funcionamiento de las 3 estaciones sismológicas colombianas ha contribuído a la mejor localización de los epicentros de los terremotos especialmente en los Andes del Norte, a fomentar el interés nacional por la sismología y por su aplicación al estudio de construcciones asismicas y a las vibraciones del tráfico, y al mismo tiempo ha redundado en bien de la sismología en un sentido más amplio y universal.

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VARIOS.

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J. E. RAMIREZ, S. J.

DANEMARK

TO THE ASSOCIATION OF SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR ON THE SEISMOLOGICAL WORK IN DENMARK 1951-1953

1) There are 3 seismological stations all belonging to the Danish Geodetic Institute. They are equipped with the following instruments :

Kobenhavn :

Galitzin-Wilip, 3 components,
Wiechert, 1000 kg horizontal,

Wiechert, 1300 kg vertical,
Milne Shaw, E component,
Benioff, short-period vertical.

Scoresby-Sund :

Galitzin-Wilip, 3 components,
Grenet, short-period vertical.

Ivigtut :

Wiechert, 1000 kg horizontal,
Wiechert, 1300 kg vertical.

The Kobenhavn and Scoresby-Sund stations recorded regularly, but at Ivigtut recording was disturbed by explosion work done in the neighbouring mine. Large explosions began in the autumn of 1951, and early in 1952 the vertical seismograph was damaged and put out of action. Recording of the horizontal seismograph was suspended at the same time. It was resumed in November, but again stopped in March 1953. Since then the station has not recorded.

Miss I. Lehmann who had been chief of the Seismological Division since 1928 retired in 1953 and was superseded by Mr. Henry Jensen.

2) No earthquakes were reported felt in Denmark 1951-1953.

3) I. Lehmann has carried on some research. The phases recorded at distances around 110° were studied in the records of the earthquake of Dec. 1, 1928. P and S as recorded in other distant earthquakes were also considered and a paper written entitled : On the shadow of Earth's core. It is being published in the *Bulletin of the Seismological Society of America.* For distances smaller than 25° the travel times of P and S were also studied. European records were used at first and the result of the study given in the paper quoted below. Later, earthquakes in Northeastern America were studied and a deviating result was found. A paper was written that has not been published yet.

I. Lehmann took part in the «Semaine d'étude» on microseismic movement in Rome in the autumn of 1951 and presented a paper : On the microseismic movement recorded in Greenland and its relation to atmospheric disturbances. This paper is in print.

During a stay at the Lamont Geological Observatory, Palisades, N. Y., I. Lehmann studied the phase Lg. The paper on Lg quoted below was presented at the Meeting of the European Commission in Stuttgart in the autumn of 1952.

4) I. LEHMANN : P and S at distances smaller than 25°. — Transactions Amer. Geoph. Union. Vol. 34, pp. 477-483. 1953.

I. LEHMANN : On the short period surface wave Lg and crustal structure. — Abstract in I.U.G.G. News letter, April 1953, pp. 248-250.

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I. LEHMANN.

ESPAGNE

RAPPORT NATIONAL (1951-1953)

Introduction

Depuis de nombreuses années, les observations et les études sur la Séismologie se réalisent sur deux plans différents : l'officiel et le privé. Le premier est intégré dans le cadre des activités scientifiques effectués par l'Institut de Géographie et du Cadastre, et le second, dans les ouvrages et les travaux de trois organismes scientifiques : L'Observatoire de l'Ebre (Tortosa), celui de Cartuja (Granada), dirigés tous les deux par les Pères Jésuites, et l'Observatoire Fabra, de Barcelone. C'est l'Institut de Géographie et du Cadastre qui aide et subventionne les activités de ces observatoires privés.

Observatoires séismologiques

Comme nous l'avons indiqué, les observatoires officiels dépendent de l'Institut de Géographie et du Cadastre. Ce sont ceux de :

Toledo. — Situé aux alentours de cette ville, lat. = 39° 52' 53" N., long. = 4° 02' 55" W. Gr. et alt. = 480,56 mètres. Le sous-sol est du Miocène supérieur.

Son équipement instrumental est composé par :

SISMOGRAPHE	Composante	Masse — *Kgs.*	Période	Amplif.	Frottem.	Amort.
Wiechert	Z	1.200	2,5	1380	0,032	4,2
Idem	E-W	1.000	11	500	0,0041	4,8
Idem	N-S	1.000	12	550	0,0027	4,5

De plus, l'Observatoire dispose d'un séismographe Wiechert de 1.000 kgs. de masse et double composante horizontale et d'un équipement complet de pendule Galitzine (à trois composantes) qui ne fonctionnent pas actuellement pour des raisons d'ordre matériel. De même, un nouveau séismographe électronique enregistreur à plume et encre est à l'heure actuelle en période d'épreuve et d'essais avancés et l'on espère qu'il pourra fonctionner dans un bref délai.

Alicante. — Situé dans cette dernière ville, lat. = 38° 21' 19",22 N,. long. = 0° 29' 14",06 W. Gr. et alt. = 35 mètres, sur Crétacé supérieur. Son équipement instrumental est le suivant :

SISMOGRAPHE	Composante	Masse — *Kgs.*	Période	Amplif.	Frottem.	Amort.
Mainka	N-S	1.000	12,0	460	0,005	5,1
Idem	E-W	1.000	12,1	450	0,004	4,8
Wiechert	Z	800	En reparación.			

Almeria. — Placé dans la banlieue de cette capitale, lat. = 36° 51' 09",07 N., long. = 2° 27' 35",18 W. Gr. et alt. 65 mètres. Sous-sol = Tuf marin (calcaire du Pliocène). Il est muni des appareils suivants :

SISMOGRAPHE	Composante	Masse — Kgs.	Période	Amplif.	Frottem.	Amort.
Mainka	E-W	750	10,0	430	0,012	2,85
Idem	N-S	750	10,2	400	0,029	4,30
Idem	Z	500	5,3	215	0,011	1,10

Malaga. — Cet observatoire se trouve dans la capitale de la province du même nom, lat. = 36° 43' 39" N., long. = 4° 24' 40" W. Gr. et alt. = 60,3 mètres. La nature du sous-sol est du calcaire triasique.

Il est pourvu des séismographes suivants :

SISMOGRAPHE	Composante	Masse — Kgs.	Période	Amplif.	Frottem.	Amort.
Málaga	NE-SW	1.600	2,8	780	0,030	6
Mainka	N-S	750	9,4	300	0,021	3
Idem	E-W	750	3,6	50	0,022	1 5
Victoria (1)	Z	100	0,3	1.600	Tg=7	30
Wizin (2)	Z	80	12,5	—	—	5

Les deux Z électromagnétiques sont accouplés au même galvanomètre.

Ténérife. — Installé à Santa Cruz de Ténérife, capitale de l'Ile du même nom dans les Iles Canarias, lat. = 28° 27' 14" N., long. = 12° 33' 06" W. et alt. = 1 mètre, sur un terrain volcanique.

Cet Observatoire, qui a commencé récemment à fonctionner, se trouve encore en période d'épreuve. Il dispose seulement pour le moment d'un séismographe à composante verticale et de courte période du type Victoria, avec les mêmes caractéristiques que celui de Malaga.

Ebro. — Cet Observatoire fait partie de l'Observatoire astronomique et géophysique de l'Ebre, dirigé par les Pères Jésuites. Il est situé à Roquetas, dans la province de Tarragone, près de l'embouchure de l'Ebre, lat. = 40° 49' 14" N., long. = 0° 29' 36" E. Gr., alt. = 50 mètres.

La nature du sol est du Conglomeré appartenant au Quaternaire ancien.

Son équipement instrumental est composé des séismographes suivants :

SISMOGRAPHE	Composante	Masse — kgs	Période	Amplif.	Frottem.	Amort.
Mainka-Ebro ...	N.	1.500	15,41	275	0,0031	4,6
Idem	E.	1.500	10,83	152	0,0027	3,4
Ebro-Vertical ...	N.	635	2,50	230	0,003	—

Cartuja. — Dirigé comme le précédent par les Pères Jésuites dans l'Observatoire du même nom établi tout près de Granada, lat. = 37° 11' 24" N., long. = 3° 35' 52",5 W. Gr. et alt. = 774,37 mètres sur sous-sol constitué par du calcaire tortonien.

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(1) Construit par l'atelier même de l'observatoire.

(2) Wiechert de 80 Kgs. transformé en Galitzin.

Son équipement instrumental est formé par :

SISMOGRAPHE	Composante	Masse — *Kgs.*	Période	Amplif.	Frottem.	Amort.
Belarmino	Z	3,5	6	—	—	—
Canisio	N-S	1,5	12	—	—	—
Idem	E-W	1,5	12	—	—	—
Cartuja max.....	E-W	4.500	10	800	0,00012	7,2
Idem bifilaire ...	N-S	340	9	75	0,0008	7,1
Idem id.	E-W	340	10	85	0,0007	7,0
Idem vertical....	E-W	370	3	200	0,0015	—

Fabra. — Observatoire privé appartenant à l'Observatoire du même nom, à Barcelona, lat. = 41° 24' 59" N., long. = 2° 08' 00" E. sur terrain d'ardoises paléozoïques.

Il dispose des appareils suivants :

SISMOGRAPHE	Composante	Masse — *Kgs.*	Période	Amplif.	Frottem.	Amort.
Mainka	N-S	140	9	60	0,1	3
Idem	E-W	140	9	60	0,1	3
Vicentini	Z	56	0,9	125	—	—

Informations macroséismiques. Etudes de séismes ressentis

Pendant la période 1951-1953, les études et informations suivantes ont été réalisées :

Le séisme de la Sierra de Lúcar (Grenade-Almeria), par *A. Rey Pastor.*

Le séisme du bas-Segura du 6 mai 1953, par *A. Rey Pastor.*

Le séisme du 28 septembre 1953, par *A. Rey Pastor* et *J. Bonelli.*

Le séisme à foyer profond du 29 mars 1954, par *J. Bonelli* et *L. Esteban Carrasco* (en étude).

De plus, par le Laboratoire central de séismologie (Ingénieur J. Bonelli et L. Esteban) on a localisé un bon nombre d'épicentres de séismes ibériques, qui apparaissent dans le *Boletin sismico* que ce Laboratoire a commencé à publier.

Travaux de recherches ; séismologie théorique et appliquée ; géographie séismologique

Cálculo de la magnitud de los seismos referida al Observatorio de Toledo, par *J. Bonelli* y *L. Esteban Carrasco.*

Sintesis de sismicidad de la Peninsula Ibérica, par *A. Rey Pastor.*

Determinación gráfica de las coordenadas epicentrales, par *J. Martin Romero.*

Ensayo sobre la sismicidad del Atlántico, par *J. Martin Romero.*

Seismology in Spain. Earthquake notes, par le *P. Due,* de l'Observatoire de Cartuja. Rev. «Urania».

El problema de los microseismos, par le *P. Due,* Rev. «Geofísica».

Movimientos sismicos en España durante 1951 (sous presse), par le *P. Due.*

Movimientos sismicos en España durante 1952, par le *P. Due* (sous presse).

El período sismico de la provincia de Jaén, par le *P. Due*. Rev. «Las Ciencias».

Die südspanischen Erdbeben von März bis August 1951, par le *P. Due*. «Neues Jahrbuch der Geologie und Paläontologie».

La agitación microsismica del suelo en Granada, par le *P. Due*. Rev. « Geofísica ».

Bibliographie générale

El bloque tectónico del Mar Menor, par *A. Rey Pastor* (en cours de publication).

Estudio Tectonofisico de la Falla del Guadalquivir, par *A. Rey Pastor* (en cours de publication).

Un nuevo sismógrafo de célula fotoeléctrica con registro de pluma y tinta, par *J. Bonelli* et *L. de Miguel* (en préparation).

Estados fisicos en las capas internas de la Tierra, par le *P. Due*. Rev. « Euclides ».

Inquietudes cientificas de la vida presente, par le *P. Due*. Rev. « Razón y Fe ».

La sismicidad del Sudeste de España, par le *P. Due*. « Boletín de Información de la Unión Geodésica y Geofísica Internacional ».

Actualidades Geológicas, par le *P. Due*. « Notas y Comunicaciones del Instituto Geológico Español ».

Nuevos recursos de la Geologia moderna, par le *P. Due* (sous presse).

Interpretación geológica de las mediciones geofísicas aplicadas a la prospección, par *J. Cantos*. Tomo V.

Qué es Geofísica ?, par *J. Cantos*. « Notas y Comunicaciones del Instituto Geológico y Minero ».

Aplicación de los métodos geofísicos a la prospección de aguas subterráneas, par *J. Cantos*. « Notas y Comunicaciones del Instituto Geológico y Minero.

La erupción del Nambroque en la isla de La Palma, par *J. Romero Ortiz*. « Boletín del Instituto Geológico y Minero », núm. 63.

Potencia radiactiva natural, par *J. M. López de Azcona*. II Congreso Nacional de Ingeniería. Tomo III.

El problema de los microsismos, par *J. M. López de Azcona*. « Notas y Comunicaciones del Instituto Geológico y Minero », núm. 25.

Velocidad aparente de propagación de las ondas sismicas longitudinales, par *J. M. López de Azcona*. « Assoc. de Séism. et de Phys. de l'intérieur de la Terre ». Série A., núm. 18.

Edad absoluta por métodos radiactivos de la formación uranifera de Sierra Albarrana, par *J. M. López de Azcona*. «Soc. Esp. de Fís. y Quím. » Madrid.

Las edades por métodos nucleares, par *J. M. López de Azcona*. « Soc. Esp. de Fís. y Quím. » Madrid.

Interpretación geofisica de las variaciones isotópicas naturales de los elementos quimicos, par *J. M. López de Azcona*. « Revista de Ciencia Aplicada », núm. 32.

FRANCE

RAPPORT NATIONAL FRANCE ET UNION FRANÇAISE 1951-1953

Etat des stations séismologiques au 1er janvier 1954

Les tableaux suivants donnent les principales constantes, au 1er janvier 1954, des appareils utilisés dans les stations séismologiques françaises et de l'Union française.

Abréviations utilisées :

A : distance (en mm) de la lentille du galvanomètre à la surface de l'inscripteur; D : vitesse de déroulement (en mm par minute ; E : facteur d'amortissement; μ^2 : degré d'amortissement (Galitzine); Gal. : appareil Galitzine; h : coefficient d'amortissement du pendule; k : coefficient d'amortissement du galvanomètre; K : facteur de transmission dépendant du couplage d'induction (Galitzine); M : masse en kilogs; lr : longueur réduite du pendule (en cm); r : déviation (en mm) due au frottement; Tg : période (en secondes) du galvanomètre sans amortissement; To ou Tp : période propre du séismographe sans amortissement; Ts : période du mouvement du sol pour laquelle le grandissement Vm est maximum; v : rapport d'amortissement corrigé du frottement (rapport de deux élongations successives corrigées du frottement); Vo : grandissement statique; Vm : grandissement maximum pour le mouvement sinusoïdal du sol de période Ts; ω : pulsation.

Alger-Université (36° 46' N, 3° 03' E, h = 59 m.)

Composante	Electromagnétique Coulomb-Grenet verticale	Electromagnétique Coulomb-Grenet verticale
Tg	0,8	3,9
Tp	1,4	10,0
M	3,161	1,001
h	0,86	0,63
k	3,23	6,52
A	910	1000
lr	14,4	18,0
Vm	6480	1400
Ts	0,4	6,3
D	60	30

Le séismographe Mainka, qui a fonctionné à l'observatoire d'Alger-Bouzaréah, a été transporté à la station d'Alger-Université où il sera prochainement remis en service après réparation.

Bagnères-de-Bigorre (43° 04' N, 0°09' E, h = 577 m.)

Composante	Mainka-S.O.M. N	Mainka-S.O.M. E
M	450	450
To	8,0	8,5
Vo	110	105
r (mm)	1,5	2,1
v	3,7	4,9
r/To²	0,024	0,029
D	15	15

Besançon (47° 14' 59" N, 0° 23' 57" E, h = 311 m.)

Composante	Appareil Courte Période (Peterschmitt) verticale
Tg	2
Tp	1,8
M	1,15
A	1120
D	45

Clermont-Ferrand (45° 45' 46" N, 3° 06' 39" E, h = 400 m.)

Composante	Coulomb-Grenet Z	Faux Wenner Z	Wenner Coulomb Grenet NS	Galitzine EW
Tg	0,85	16	7,7	10,9
Tp	1,46	15,0	15,0	15,0
A	1000	1000	1000	1000
Vm	3400	517	370	360
Ts	0,68	2,0	4,0	3,0
D	60	30	30	30

Marseille (43° 18' 16" N, 5° 23' 36" E, h = 75 m.)

Composante	Mainka N	Mainka N
M	150	150
To	8,6	8,8
Vo	58,5	61,7
r (mm)	1,9	1,8
v	4,1	3,25
D	13	13

Morne des Cadets (Martinique) (14° 44' 00" N, 61° 09' 20" W, h = 510 m.)

Composante	Quervain-Piccard Z	Quervain-Piccard E	Quervain-Piccard N
M	20 tonnes	20 tonnes	20 tonnes
To	1,8	3	3
Vo	1300	1580	1560
r(mm)	1	2,5	2,4
v	1/3	1/4	1/4
r/To²	0,31	0,28	0.27
D	60	60	60

En outre, depuis 1953 fonctionne un séismographe électrostatique à inscription mécanique dont les caractéristiques sont les suivantes :

Pendule Joset à condensateurs NE-SW : To = 12 s.; amortissement critique; constante de temps du circuit d'attaque (2 lampes 954 montées en électromètre) : RC = 2 s.

Trois amplificateurs commandent chacun un enregistreur sur noir de fumée; ampli 1, 2 liaisons : RC = 4 s., Vo = 2000; ampli 2, 2 liaisons : RC = 4 s., Vo = 200; ampli 3, 3 liaisons (1-2 : RC = 4; 2-3 : RC = 0,135), Vo = 20000.

Les réponses sont semblables, sauf pour les périodes très courtes, à celles des pendules à enregistrement direct de 8 s. pour les 2 premiers amplis et 1 s. pour le troisième. L'influence du frottement est négligeable. Cet appareil fera prochainement l'objet d'une description détaillée. (M. Molard.)

Un appareil analogue vient d'être mis en service à La Guadeloupe.

Un séismographe électrostatique à longue période (T équivalente est voisine de 2 minutes) est en cours de montage.

Paris (Parc Saint-Maur) (48° 48' 34" N, 2° 29' 37" E, h = 47 m.)

I. — Appareils à galvanomètre

Composante	Galitzine Z	Grenet Z	Faux-Wenner Z
Tg	12,0	0,63	42,4
Tp	12,1	1,17	13,3
M	7	3,030	2,997
μ^2	0,004	—	—
e/ω (galv.)	—	0,707	0,75
e/ω (pendule)	—	0,707	7,2
A	100	89,5	100
Ir	39,2	12,6	19,1
Vm	1100	45000	900
Ts	7	0,7	20
D	20	60	20

Un pendule horizontal à grande période est en construction : Tg =40s.; Tp = 25 à 30s.; le pendule et le galvanomètre étant suramortis.

II. — Appareils mécaniques

Composante	Wiechert N	Wiechert E
M	1000	1000
To	12	12
Vo	225	225
r (mm)	0,8	0,8
v	5	5
D	15	15

Saint-Claude (Guadeloupe) (16° 02' N, 61° 41' W, h = 646 m.)

I. — Appareils à galvanomètre

Composante	Molard N	Electrostatique N
Tp	8	8
M	0,3	0,3
Vm	20.000	3000
D	60	60

Amortissement critique; enregistrement sur noir de fumée par galvanomètre Pekly.

II. — Appareils mécaniques

Composante	Mainka-S.O.M. N	Mainka-S.O.M. E
M	450	450
To	6	6
Vo	150	150
v	5	5
D	30	30

Strasbourg (48° 35' 05" N, 7° 45' 57" E, h = 135 m.)

I. — Appareils à galvanomètre

Composante	Gal. Z	Gal. N	Gal. E	C.P.P. Z
Tg	11,25	22,7	19,35	1,2
Tp	11,2	22,9	19,4	0,8
K	110,2	39,6	31,4	—
μ^2	0,06	0,00	0,00	—
A	1000	1000	1000	1000
Ir	427,7	124,2	102,0	—
Vm	305	750	620	5000
Ts	6,5	13,0	11,0	1,0
D	30	30	30	60

II. — Appareils mécaniques

Composante	Wiechert N	Wiechert E	Wiechert Z	19 tonnes N	19 tonnes E
M	1000	1000	1300	19000	19000
To	7,2	7,4	3,3	1,9	1,5
Vo	305	255	230	1110	1245
r (mm)	4,1	2,9	1,5	1,1	1,4
v	3,2	4,3	4,3	5,2	5,5
r/To²	0,079	0,053	0,138	0,305	0,621
D	15	15	15	60	60

Tamanrasset (22° 47'5 N, 5° 31'4 E, h = 1395 m.)

Composante	Electromagnétique Coulomb-Grenet verticale	Electromagnétique Coulomb-Grenet verticale
Tg	0,75	3,85
Tp	1,8	10
M	5,925	1,134
h	1,17	11,76
k	1,15	0,68
A	910 mm	3110 mm
Ir	0,69	17,5
Vm	46700	3090
Ts	1,16	4,1 à 6,2
D	60	30

Lomé (Togo) (6° 07'3 N, 1° 12'8 E, h = 5 m.)

Composante	Mainka-S.O.M. N	Mainka-S.O.M. E
M	450	450
To	10	10
Vo	150	150
r (mm)	2	2
v	4	4
D	15	15

M' Bour (Sénégal) (14° 23' N, 16° 57' W, h = 3 m.)

I. — Appareils à galvanomètre

Composante	Grenet-Coulomb (Montage Wenner) Z
Tg	4,2
Tp	9,5
M	1318
h	0,90
k	3,1
A	960
lr	18,1
Vm	1550
Ts	1,45
D	18

II. — Appareils mécaniques

Composante	Mainka-S.O.M. E	Mainka-S.O.M. N
M	450	450
To	10,0	9,5
Vo	44 mm/5 g	45 mm/5 g
r (mm)	1,0	1,2
v	4,3	4,8
r/To^2	1/100 mm/sec	1,3/100 mm/sec
D	15	15

Nouméa (Nouvelle Calédonie) (22° 18' 10" S, 166° 27' 20" E, h = 5 m.)
Institut Français d'Océanie, Boîte postale N° 4

Composante	Coulomb-Grenet Z
Tp	6,0
Vm	300
D	20

La station fonctionne depuis le 1er février 1954 et doit être complétée par l'installation d'autres appareils.

Tananarive (Madagascar) (18° 55' S, 47° 33' E, h = 1.375 m.)

I. — Appareils à galvanomètre

Composante	Grenet Z
Tg	0,8
Tp	1,4
Vm	8000
Ts	1
D	60

II. — Appareils mécaniques

Composante	Mainka-S.O.M. N	Mainka-S.O.M. E
M	450	450
To	9,6	9,0
Vo	124	121
r (mm)	0,4	1,0
v	2,6	4,2
r/To^2	0,005	0,012
D	15	15

Il n'a pas été fait mention ici des stations d'Averroes (Maroc) et de Tunis (Tunisie), décrites dans les rapports nationaux correspondants.

Signalons encore qu'une station séismologique est en voie d'installation au Musée Océanographique de Monaco.

Enquêtes macroséismiques en France et dans l'Union française.

46 secousses ont été ressenties en France pendant la période 1951-1953; la répartition géographique est la suivante :

Pyrénées : 24; Alpes : 8; Fossé rhénan et Vosges : 8; Massif Central : 2; Bretagne : 1; Corse : 1; secousses ayant leur foyer à l'étranger : 2. Il faut y ajouter une dizaine au moins d'autres légères secousses ressenties dans la région épicentrale de l'essaim séismique de Basse-Alsace.

L'activité séismique a été particulièrement forte dans les Pyrénées, les foyers se localisant dans la zone frontale nord-pyrénéenne fortement plissée : l'intensité VII a été atteinte le 13 octobre 1953, à 16 h. 45 m. aux environs de Campan (43° 11' N, 0° 13' E) et le 7 février 1952, à 14 h. 28 m. au sud d'Aramits (43° 1 N, 0° 8 W); le 5 avril 1952, à 00 h. 05 m., de légers dégâts ont été provoqués à Arras, Salles, Lourdes, Luz, etc... (épicentre au sud de Lourdes 43°0 N, 0°0 long.).

Deux séismes « pré-alpins » caractérisés par une intensité relativement forte à l'épicentre et par une zone macroséismique très réduite ont provoqué des dégâts à Chasteuil et Talloire le 30 novembre 1951, à 06 h. 08 m. (épicentre 43° 51' N, 6°24' E) et à Pierrelongue le 8 juin 1952, à 22 h. 15 m. (épicentre : 44°2 N, 5°2 E).

Un curieux essaim d'une trentaine de secousses s'est produit en Basse Alsace en août, septembre et octobre 1952. Aucun épicentre macroséismique net n'a pu être déterminé. L'épicentre microséismique a pour coordonnées 49°0 N, 8°0 E.

En Algérie, l'Institut de Météorologie et de Physique du Globe continue à étudier l'activité séismique : 160 secousses environ ont été ressenties. En 1951, plusieurs secousses ont provoqué des dégâts dans les Babors; le degré VI a été atteint le 1er avril 1952, à 04 h. 20 m., dans la région d'Oued-Zenati et de Medjez Amar (36°2 N, 7°3 E); les chocs du 5 juillet 1953, à 04 h. 40 m. et du 22 août 1953, à 01 h. 28 m., ont provoqué d'importants dégâts à Aumale, Bir Rabalou, Bertville (36°2 N, 3°6 E); enfin, la secousse du 29 août 1953, à 14 h. 09 m., a détruit partiellement le douar Frikat dans les monts du Hodna (35°8 N, 5°4 E).

A la Martinique s'est produit le 19 mars 1953, à 08 h. 27 m., un important séisme à foyer profond (150 km environ) dont l'épicentre était situé au SW de l'île. Des dégâts ont été causés à Fort-de-France, où la cathédrale et plusieurs bâtiments ont été endommagés; il y a eu 3 blessés légers; la secousse a été ressentie à la Martinique (VI-VII), à Sainte-Lucie (VI) et à la Barbade (VI), à la Guadeloupe (V), à Trinidad (VI) et dans les Guyannes (V). La magnitude a atteint 7¼ à 7¾.

A Madagascar l'activité séismique est étudiée par le R. P. Poisson; elle reste voisine d'une dizaine de secousses par an. Le 20 janvier 1953 et les jours suivants une série de secousses qu'on peut considérer comme la manifestation d'une éruption volcanique avortée ont été ressenties dans l'Ile de la Grande Comore et plus particulièrement à Moroni sur les pentes sud du Volcan Karthala.

A la Réunion, un service d'observations macroséismiques a été organisé et de légères secousses ont été signalées.

Bulletins.

Le Bureau Central séismologique français à Strasbourg continue à assurer la concentration des bulletins décadaires ou mensuels des stations de la France métropolitaine et de l'Union française; un bulletin mensuel rassemble toutes ces données.

Les dépouillements sont publiés sous leur forme définitive dans les Annales de l'Institut de Physique du Globe de Strasbourg dont la deuxième partie (Séismologie) est l'organe du Bureau central séismologique français. Les fascicules contenant les observations effectuées en 1947, 1948 et 1949 ont été publiés ; le manuscrit des données de l'année 1950 est en voie d'achèvement. Des notes macroséismiques et des renseignements bibliographiques concernant les séismes ayant fait l'objet d'études particulières figurent dans ces fascicules.

L'Institut de Physique du Globe de Strasbourg participe à la préparation du Bulletin mensuel du Bureau international de Séismologie. Ce Bulletin a pris de plus en plus d'ampleur au fur et à mesure qu'entrent en fonctionnement des stations nouvelles équipées de séismographes à haute sensibilité : 1446 séismes ont été étudiés pour l'année 1951, 1672 pour l'année 1952, 1693 pour l'année 1953.

Géophysique appliquée.

La Compagnie générale de Géophysique a accru progressivement le nombre de ses équipes; en 1953 18 équipes étaient au travail en France et dans l'Union française; plus de 20.000 forages d'explosion ont été exploités. Des équipes légères sont spécialisées dans l'étude

des problèmes à faible profondeur (séismique-réfraction). Des travaux ont été effectués en mer dans la baie du Mont-Saint-Michel. Les méthodes ont été perfectionnées (multiplication des séismographes : jusqu'à 36 par trace; multiplication des charges, 10 charges multiples par exemple). On trouvera plus loin dans la bibliographie plusieurs articles relatifs aux méthodes et aux résultats de la prospection séismique.

Missions arctiques et antarctiques.

On a rappelé dans le précédent rapport triennal les travaux de prospection séismique entrepris au Groenland par les Expéditions P. E. Victor. Ces travaux, marqués le 4 août 1951 par l'accident mortel survenu à A. Joset, ont pu être cependant poursuivis sous la direction de J. J. Holtzscherer. 215 sondages par réflexion séismique effectués sur un parcours total de 5360 km ont pu être dépouillés. L'épaisseur de glace dépasse 3.000 m. au centre du Grœnland; une carte de l'altitude du fond rocheux a pu être tracée. Les résultats obtenus feront l'objet d'une communication à l'Assemblée de Rome.

En 1952 et 1953 M. Holtzscherer a poursuivi l'étude séismique de la partie nord de l'inlandsis groenlandais en collaboration avec l'Université de Georgetown (Washington) et avec le Stanford Research Institute (Californie). L'ensemble des résultats confirme les mesures effectuées les années précédentes.

En Terre Adélie J. Imbert a pu également réaliser quelques sondages séismiques et trouver des épaisseurs de glace relativement faibles (200 à 400 m.).

La station séismique de Port-Martin, en Terre Adélie (66° 49' S, 141° 24' E) a fonctionné de juillet 1950 à janvier 1952, date à laquelle elle a été détruite par un incendie. Les enregistrements obtenus ont permis à B. Imbert d'apporter une contribution à la géographie séismologique de la partie Sud-Ouest du Pacifique. L'agitation microséismique sur la côte de la Terre Adélie a également fait l'objet de recherches.

Enfin la mission des Terres Australes (Ministère de la France d'Outre-Mer) a installé en 1953 une station séismologique à Port-aux-Français dans les Iles Kerguelen (49° 29' S, 70° 13' E). Quelques télégrammes ont déjà été reçus. Une station tripartite pour l'étude des microséismes, très violents dans cette région, est en voie d'aménagement.

Recherches et bibliographie (1951-1953)

Les travaux de recherches ont été nombreux, on en trouvera ci-dessous la bibliographie. Des domaines variés ont été explorés : agitation microséismique (3, 6, 7, 8, 9, 10, 29, 52, 65, 81); raz de marée (28); ondes T, ondes superficielles, propagation des ondes (13, 20, 21, 22, 23, 55, 56, 57, 70); appareillage (11, 30, 35, 42, 72); géographie séismologique, détermination des épicentres, études des séismes proches, magnitude (12, 27, 60, 63, 66, 67, 69, 71, 73, 74, 75, 78, 79, 82, 87, 94); graphiques de temps de propagation (64); prospection séismique (1, 2, 15, 32, 37, 53, 68, 76, 77); sondages glaciaires (14, 49, 50, 51, 58, 59, 90). Deux ouvrages intéressant les séismologues ont été publiés (24, 39).

Plusieurs branches de la Physique de l'Intérieur de la Terre ont

également fait l'objet de recherches : géothermie (16, 17, 25, 40) ; radioactivité (18, 31, 45, 46, 47, 48, 95) ; prospection radiogéologique (4, 5, 44, 84, 89) ; tectonophysique (33, 36) ; viscosité (92) ; marées terrestres (54) ; interprétations gravimétriques (19, 34, 41) : rotation de la Terre et séismes (93).

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GRANDE-BRETAGNE

BRITISH NATIONAL REPORT FOR SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR

Personal. Dr P. L. Willmore left in 1952 to take up a post at the Dominion Observatory, Ottawa, in connexion with the geophysical survey of Canada. Otherwise there are no changes to report.

Observatories. These remain as stated in the report for 1951.

Theoretical Research. Miss M. Newlands has published her paper on the disturbance due to a line source in a semi-infinite medium with a single surface layer. This is an extension of the work of E. R. Lapwood, mentioned in the report for 1951. It includes detailed expressions for the forms of the phases.

Dr Stoneley has continued his investigation of the polarization of the S phase. He has also examined, by means of the Rayleigh approximation, the propagation of Rayleigh waves in a double surface layer. This work confirms the results previously found for Eurasia by a study of Love waves, and indicates a total thickness of 35-40 km. for the continental layers, according to the assumed ratio of the thicknesses of the upper and intermediate layers. Improved accuracy is being sought by a full solution of the equations. This is a problem of great numerical complexity, but Dr Stoneley hopes to solve it by means of the EDSAC electronic machine at Cambridge.

Professor K. E. Bullen has given theoretical amplitudes for waves, if they exist, that have passed through the inner core as S.

Sir Harold Jeffreys has discussed the times of P with special reference to the possibility of regional variation. The stations were classified by azimuth so as to remove most of the errors due to uncertainty of the epicentres. In Europe the velocity up to 8° is higher than is given by the tables in use, but in Japan the times agree closely with the tables. North American earthquakes gave no clear result, since there was no case where observing stations in similar azimuths were spread over a sufficient range of distance. There were several European and Japanese earthquakes, well observed at great distances, with epicentres that could be well located by means of observations at short distances. No significant differences

of travel times were detected at distances over 70°; in particular the times to these distances across the Pacific and Eurasia appeared to be equal. In both European and Japanese earthquakes there is a strong curvature of the time-curve near 20°, but the data do not decide whether this is best represented by a continuous curvature or by a discontinuity of slope.

Experimental. Dr. J. Darbyshire, of the National Institute of Oceanography, has made a detailed examination of microseisms, comparing all three components, and finds that they are a mixture of Rayleigh and Love waves.

H. M. Colonial Office has set up eight stations in the West Indies, equipped with Willmore seismographs.

Seismic survey methods have been used by the Cambridge Department of Geodesy and Geophysics on the estuaries of the rivers Erme, Tawe and Torridge (Devon), by Dr. P. B. Mac Farlane, under the direction of Dr. M. N. Hill.

Seismic work at sea continues. In the Eastern Atlantic sediments rest directly on material where the velocity of P is between 6 and 7 km/sec; velocities of about 8 km/sec are reached at a depth of 9 to 13 km.

The world cruise of *H.M.S. Challenger* ended late in 1952. A total of 31 refraction shooting lines and numerous reflection shots were undertaken in the Atlantic, Pacific and Indian Oceans and in the Mediterranean Sea. These results are now being worked out in detail but in general it has turned out that the deep ocean sediment thickness and the velocity of compressional waves in the rock below the sediments do not change markedly between the three oceans. In the Mediterranean near the continental edge and in the neighbourhood of volcanic isles generally rock layers exist with velocities of between 4 and 5.8 km/sec.

A method has been developed by M. N. Hill and A. S. Laughton for the direct measurement of velocities of elastic waves by means of ultrasonic pulses. This has been applied to several rocks, including samples from a borehole in the Mesozoic sediments, recently made at Cambridge by the Geological Survey.

Physics of the Earth's Interior.

Dr. H. Hughes has measured the excitation energy of olivine and carried out a theoretical comparison of the results with those of S. Chapman and A. T. Price on the distribution of electrical conductivity in the mantle. Three different mechanisms of semiconduction appear to be involved : impurity, intrinsic, and ionic. The results permit estimates of temperature down to the core boundary.

Dr. R. Hide has carried out experiments on thermal convection in a rotating liquid, with possible application to eddies in the Earth's core.

Sir H. Jeffreys and Miss M.E.M. Bland have studied the theory of thermal convection in a sphere of high viscosity. The object was to test a theory of G.F.S. Hills, designed to explain how the acidic rocks collected into the continental masses. The results on the whole are favourable.

Professor A.L. Hales, while on a visit from Cape Town, made a reexamination of the thermal contraction theory of mountain formation. A special feature is that the yield in the zone of stretching is considered to be by fracture instead of flow, as had usually been assumed. This seems to provide a better explanation of geosynclines.

Dr. E. R. Lapwood has investigated thermodynamic effects that can arise owing to contraction of the Earth. He finds that the heating due to contraction is small, and is more than counteracted by the extra cooling produced by increased temperature gradients.

Experimental determinations at the National Physical Laboratory have shown that the heat of fusion of iron is 64-65 cal/gm. and that the volume expansion is 3±0.5 per cent. These determinations have enabled Professor F. E .Simon to make estimates of the melting temperatures of iron at pressures up to 4×10^6 atmospheres ; it seems likely that the temperature in the Earth's core is in the neighbourhood of 4000° K.

A discussion on the floor of the Atlantic Ocean took place at the Royal Society on 1953 February 28. It was led by Sir Edward Bullard and 17 speakers took part.

Sir Edward Bullard has made measurements of the flow of heat through the floor of the Atlantic Ocean. The mean heat flow at five stations was 0.98×10^6 cal/cm.^{2} sec.

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The International Seismological Summary.

The I.S.S. continues to be housed at Kew Observatory. Considerable progress has been made since the Brussels meeting. In July 1951 the last part issued was for 1939 October-December. In March 1954 the last is for 1944 October-December, so that five years' data have been published in 2¾ years.

The parts issued for the war years up to 1942 were not much smaller than in previous years, but the later ones are substantially smaller. It remains to be seen whether the rate of preparation can be maintained when the post-war recovery takes place.

There have been several changes of staff. Miss Hunter, now Mrs Sykes, who had done the greater part of the computation since 1946, has left. Mr. B. Elliott stayed for two years before leaving for military service. A Cambridge graduate in mathematics, Mr. J. H. Mc Donnell, was engaged last year but stayed for only six months. Several others have stayed only a short time. The present staff consists of Mr. Hughes, Mrs. I. Sanders, Miss V. Howe and Miss J. D. Batten. The normal number is five. It is particularly desirable that there should be an additional graduate, but we cannot offer prospects of promotion that would compete with the Civil Service and Industry.

The possibility of production by photo-lithography has been investigated, expert assistance being provided by the Royal Society. It appeared that some saving might be possible, but that the amount would be small. This is largely due to the very favourable terms offered by our printers. The largest item in the time taken for preparation is in the copying of observations from the bulletins on to cards, so that all data for each earthquake can be kept together, and there seems to be no way of avoiding or shortening this part of the procedure.

The chief items of income and the total expenditure have been as follows.

	Unesco £	*H.M. Treasury* £	*U.G.G.I.* £	*Expenditure* £
1951 (10 months)	2143	2000	—	1961
1951-2	1857	2000	—	3610
1952-3	1428	—	—	3441
1953-4 (to Mar. 31)	—	1000	200	2000 (approx.)

The Unesco Grant of £ 2035 was received in April. The cash in hand on Aug. 31 was £ 2759.

The Treasury grant is conditional on the publication of seven quarterly parts per year and the receipt of a grant from the U.G.G.I. The fluctuations of income continue to give ground for anxiety.

I should like to record my thanks again to the Director of the Meteorological Office for accomodation at Kew Observatory and to Dr. G. D. Robinson for help with the administration. The printers, the Isle of Wight County Press, have helped greatly by increasing the rate of printing to keep pace with preparation.

I am due to retire from my post at Cambridge in 1956. This will be before the next general meeting of the U.G.G.I., and I wish to cease to be Director of the I.S.S. then or sooner. The I.S.A. should therefore consider at Rome what arrangements it wishes to make for the future of the I.S.S.

HAROLD JEFFREYS.

GRÈCE

THE EARTHQUAKE STUDY IN GREECE, 1951-1953

The principal seismographic station in Greece is the *Seismological Institute of Athens Observatory.* This station is equipped with a set of Wiechert Seismographs, one astatic horizontal seismograph (1000 Kg.) and one vertical seismograph (1300 Kg.). The Seismological Laboratory of Athens University operates one Mainka horizontal seismograph (93 Kg.) appropriate for the registration of major earthquakes occurring in the Greek area. Owing to damages done to the recorder of the short-period vertical Benioff instrument during its transportation and to the necessity of a new vault at a fair distance from traffic, the installation of this new instrument of high magnification, which was given to the University of Athens by the Canadian Council for Reconstruction with a Hamilton chronometer and a radio receiver of time signals modified for operating recorder relays, was delayed, but it is now believed to be accomplished in next summer.

The distribution of a preliminary seismic Bulletin with the readings of the seismic records and the corresponding observational data systematically collected with postcard questionnaires has been regularly continued. Three Bulletins (N° 1-3), containing the final interpretation of the seismic records and the intensities of all the shocks felt in Greece on Mercalli-Sieberg scale, were in the meantime issued by the Seismological Institute for the years 1950-1952. On each Bulletin a map is annexed showing the distribution of the seismic activity in the Greek area with the epicenters of the major earthquakes and the corresponding area of highest intensity according to the gathered reports of felt shaking. A Catalog of earthquakes covering the lack of information during the period 1879-1892 was

published by the Seismological Laboratory of the University (« Katalog der Erdbeben in Griechenland für die Zeit von 1879 bis 1892 », Ann. Géol. pays Helléniques, T. 5 (1953), 114-229).

During the period 1951-1953 covered by this report two papers were published on the seismicity of the Islands Leukas and Chios by A. Galanopoulos (« Die Seismizität der Insel Leukas », I. Allgemeine historische Übersicht. Gerl. Beitr. z. Geoph., Bd. 62, Heft 4 (1952), 256-263; II. Die Erdbeben vom 22. April und 30. Juni 1948. Ebenda, Bd. 63, Heft 1 (1954), 1-15; « Die Seismizität der Insel Chios ». Ebenda, Bd. 63, Heft 4 (1954), 253-264), one paper on the destructive earthquake of the Chalkidiki - Peninsula, September 26, 1932, by G. Georgalas and A. Galanopoulos (« Das grosse Erdbeben der Chalkidike vom 26. September 1932 », Bul. of the Geol. Soc. of Greece, T. I, N° 1 (1953), 11-62) and one paper on the earthquakes of the Crete Island, in Greek, by E. Platakis (Ann. de l'île de Crète, T. 4 (1950), 463-524).

Prof. Dr. A. G. GALANOPOULOS.

HONGRIE

RAPPORT SUR LES TRAVAUX DE SEISMOLOGIE ET DE PHYSIQUE DE L'INTERIEUR DE LA TERRE

L'Institut National Séismologique chargé du service séismologique en Hongrie fonctionne depuis 1952 au sein de l'Institut Géophysique Eötvös Lóránd. Il y a des observatoires à Budapest, Kalocsa, Kecskemét et Szeged. A la suite des événements de guerre, l'Institut a subi de considérables dommages : en partie ce sont les bâtiments abritant les instruments, en partie les instruments mêmes qui ont été ruinés à toutes les quatre stations. Après avoir effectué les réparations nécessaires, la station de Budapest a repris son activité le 1er octobre 1945, celle de Kalocsa le 1er octobre 1945, celle de Kecskemét le 1er juillet 1951, enfin celle de Szeged le 1er février 1952.

A l'Institut Central Séismologique de Budapest c'est un séismographe horizontal de 1000 kg, type Wiechert, qui fonctionne actuellement, la réparation du séismographe vertical de 80 kg, type Wiechert, et le montage du séismographe à 2 composantes et enregistrement optique, type Krumbach sont en train d'être effectués.

L'équipement de la Station Séismologique de Kalocsa comprend un séismographe horizontal de 200 kg type Wiechert, celui de la station de Kecskemét un séismographe horizontal de 100 kg, type Krumbach, et celle de Szeged un séismographe horizontal de 210 kg type Mainka. L'équipement instrumental est en train d'être complété. (Vu que des rapports semblables n'ont pas été publiés depuis la deuxième guerre mondiale, nous résumerons en ce qui suit les travaux effectués depuis cette époque.)

Le matériel hongrois du catalogue microséismique a paru chaque année dans la publication de l'Institut National Séismologique et a été régulièrement envoyé aux différents instituts de séismologie.

Le matériel macroséismique des tremblements de terre du pays a été également élaboré chaque année. Les publications y relatives constituent la base d'un échange de périodiques avec les différents instituts de séismologie. En plus nous avons fait paraître un catalogue comprenant les tremblements de terre des bassins des Carpathes à partir de 455 jusqu'à 1918.

La courbe de propagation résumant les données des tremblements proches est destinée à faciliter les mesures de séismogrammes de notre station centrale. L'élaboration des données microséismiques du tremblement du 10 juillet 1949 au Turkestan a fourni, en dehors de l'établissement de l'épicentre et du temps d'origine du tremblement, aussi les courbes de propagation. La construction en voie d'achèvement d'un séismographe de forte amplification pour l'enregistrement des tremblements proches servira à compléter notre équipement instrumental. La carte séismographique de la Hongrie dressée à la base des données à disposition non seulement fournit des indications relatives à l'activité séismique du sol du pays, mais encore peut servir à des buts pratiques, telles les mesures de protection contre les dommages causés par les tremblements. On est en train de compléter la carte par de nouvelles données. Dans quelques villes, nous avons étudié, à la base du matériel d'observation dont nous disposons, les relations entre l'intensité locale du tremblement et la structure du sol. Lors du choix de l'emplacement de grandes constructions industrielles, on a procédé à des recherches en vue de leur protection économique contre les dommages causés par les tremblements.

Selon une étude relative à la géophysique régionale de la Transdanubie, le mouvement régional de celle-ci est de caractère isostatique. C'est également ici qu'on a constaté, à la base de l'examen comparatif des épicentres séismiques et des indications géophysiques, que les plus grandes masses mézozoïques et paléozoïques de la Transdanubie se comportent en blocs aséismiques et que leurs surfaces de contact possèdent une vive séismicité. Une autre étude démontre un mouvement de l'écorce conforme à la théorie de l'isostasie le long de deux sections d'Europe Centrale / Ajaccio-München et Hajduszoboszló-Tarnopol /. Selon les recherches séismologiques de Calol, l'épaisseur de l'écorce de granit diminue de 8 à 10 km de l'extrémité nord de la section Ajaccio-München jusqu'à la mer ligurienne, résultat qui, d'après l'auteur, est confirmé aussi quantitativement par les résultats des mesures gravimétriques. Une troisième étude établit une relation entre les anomalies isostatiques et les directions orogénétiques selon laquelle les mouvements se dirigent du domaine des maximums isostatiques vers les dépressions. Une quatrième étude démontre, à la base de données gravimétriques et de variations de niveau, le caractère isostatique des mouvements de l'écorce terrestre en Hongrie. L'auteur établit une relation provisoire pour la correction temporelle des valeurs de la hauteur des points de base de nivellement situés sur la Plaine Hongroise.

Une cinquième étude démontre, à la base de données gravitationnelles et séismiques, que l'écorce terrestre est presque partout

en équilibre isostatique. L'auteur esquisse un modèle local plus exact de la réduction isostatique et déduit quelques conséquences géologiques des résultats. Une sixième étude fournit une explication extrêmement simple de la formation des fosses du fond de la mer, ainsi que les preuves physiques de l'explication. Les conclusions qualitatives de la théorie sont en bonne conformité avec les observations géophysiques.

Dans les études traitant des bases de la géomécanique et son application à quelques phénomènes géologiques, ainsi qu'à la terre et ses parties plus ou moins grandes, on trouvera une nouvelle interprétation des structures à plissement et à fracture des montagnes, de nombreux phénomènes carstiques, de l'orogénèse, de la loi du changement du climat global, de beaucoup de problèmes hydrologiques, de la question des mouvements du magma, de la relation des matières minéraux utilisables et de la structure des montagnes, de la province magmatique, de la formation de l'écorce terrestre, de la structure des Carpathes, des Alpes, des Apennins et en général des montagnes à chaîne et en particulier de la formation de caractère cratogène des montagnes de la Hongrie. Ces études aboutissent à une loi importante concernant la structure des montagnes, à son interprétation géomécanique, et par là éclaircissent des rapports géologiques et relatifs à la structure des montagnes, rapports généraux, clairs et facilement applicables.

Nos prospections de roches effectuées par des méthodes radioactives s'étendent aussi bien aux roches éruptives qu'aux roches sédimentaires.

Des valeurs d'activité des roches éruptives, en bonne conformité avec les valeurs connues de la littérature internationale, nous avons déduit des conclusions génétiques.

Les examens des sédiments ont permis non seulement de faire des constatations de caractère géochimique, mais encore de reconnaître, à l'aide de l'analyse de certains gisements de charbon en milieu granitique, le rôle de l'acide d'humus dans la migration de l'uranium.

Il a été établi que les gisements de bauxite dans la proximité des gisements de granit se distinguent d'autres gisements par leur valeur de radiation. L'analyse des sédiments de nos champs d'huile est destinée à l'identification, voire distinction des couches.

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COMITE GEODESIQUE ET GEOPHYSIQUE
ACADEMIE HONGROISE DES SCIENCES

INDIA

NATIONAL REPORT ON SEISMOLOGY (1951-53)

1. —

Seismological Observatories in India and their Instrumental Equipment.

Seismological work in India is under the Meteorological Department of the Government of India. This department is responsible for maintaining a network of seismological observatories in the country and for seismological research and development. Field studies after the occurrence of a major shock are made by the Geological Survey of India who usually publish a report after each major earthquake. Till the end of 1952 the Headquarters of the Seismological Organisation was located at Poona, but in January 1953 it was shifted to Shillong, Assam. A partially underground vault with a channel of dead air around it has been constructed and equipped with modern types of Seismographs like the Benioff Vertical Seismograph and Wenner three component accelerograph.

A list of Seismological Observatories in India with their instrumental equipment is given below :

Station	*Instruments in operation*
1. *Shillong* (Central Seismological Observatory and Headquarters of the Seismological Organisation in India) (25° 34' N, 91° 53' E)	1 Benioff vertical seismograph (short period) 1 Sprengnether type, electromagnetic seismograph 1 Milne-Shaw seismograph 3 Wood-Anderson type torsion seismographs 1 Wenner, three component accelerograph
2. *Bombay* (Colaba) (18° 54' N. 72° 49' E)	2 Milne-Shaw Seismographs 1 Wood-Anderson type torsion seismograph 1 Sprengnether microseismograph 2 Omori-Ewing seismographs
3. *New Delhi* (28° 35' N, 77° 12' E)	1 Milne-Shaw seismograph 2 Wood-Anderson type torsion seismographs 1 Omori-Ewing seismograph
4. *Calcutta* (22° 32' N, 88° 22' E)	1 Milne-Shaw seismograph 1 Wood-Anderson type torsion seismograph 2 Omori-Ewing seismographs
5. *Kodaikanal* (10° 14' N, 77° 28' E)	1 Milne-Shaw seismograph

6. *Madras* (13° O' N, 80° 11' E)	1 Sprengnether microseismograph
7. *Poona* (18° 32' N, 73° 51' E)	1 Sprengnether vertical seismograph 1 Milne-Shaw seismograph 1 Wood-Anderson type torsion seismograph
8. *Dehra Dun* (30° 19' N, 78° 02' E)	2 Wood-Anderson type torsion seismographs 1 Milne-Shaw seismograph
9. *Tocklai* (26° 45' N, 94° 46' E)	1 Wood-Anderson type torsion seismograph

Seismograph stations are also functioning at the following stations and they co-operate with the India Meteorological Department by sending their data for publication in the Seismological Bulletins issued by the Department :

10. *Chatra* (Central Water and Power Commission) (26° 50' N, 87° 10' E)	1 Benioff vertical seismograph (short period) 2 Wood-Anderson type torsion seismographs 1 Milne-Shaw seismograph 1 Wenner three component accelerograph
11. *Hyderabad* (Hyderabad State) (17° 26' N, 78° 27' E)	2 Milne-Shaw seismographs

N. B. — The Department of Meteorology of Ceylon has a seismograph station at Colombo with 1 Milne-Shaw seismograph. This station also co-operates with the India Meteorological Department by sending their data for publication.

A Seismological Observatory with a complete set of Benioff instruments (two horizontal and one vertical) of the variable reluctance type is functioning in the Geophysical Laboratory of the Bengal Engineering College at Shibpore, Howrah (22° 33' 15,5" N. 88° 18' 33,5" E). A microseismic recorder is also connected to the second channel of the two horizontal components.

Arrangements are in progress to open a seismograph station at Bokaro (Thermal Power Station of the Damodar Catchment area) in the near future. Steps have also been taken to start the observatory at Bhakra (in the Sutlej Catchment area, the Punjab).

Microseismograph Stations

Microseismographs in a tripartite set up have been installed at Madras and a microseismograph station is expected to be opened

also at Colaba (Bombay) this year, for studies of microseisms in relation to weather in the Indian seas.

Records of microseisms associated with disturbed weather are taken on an open time scale at the Geophysical Laboratory of the Bengal Engineering College, Howrah, to study the correlations between microseisms and sea waves, swells and cyclonic disturbances.

2. —

Macroseismic Research, Study of the effects of seismics

(*a*) Considerable data relating to various effects of the Great Assam earthquake of 1950 were collected from answers to questionnaires circulated to different parts of India, Burma, Nepal and Lhasa. Some of these materials and records were analysed with a view to discuss the epicentre, origin time, depth, magnitude etc. of the earthquake. The energy was calculated as 3×10^{27} ergs and the horizontal acceleration on alluvial ground at the epicentre was estimated as 5 g. Isoseismals of the earthquake of 1950 were delineated from all the available materials and completed in the North-East sector of the epicentre from where no macroseismic information was available, from an analogy of the Kansu earthquake, 1920. The total felt area was estimated about 1.3 million square miles and the depth of focus from the radius of perceptibility was calculated to be about 18 kms.

(*b*) Explosive sounds were heard as an effect of the earthquake of 1950 at a large number of places round the epicentre. These were definitely heard up to a distance of 757 miles from the epicentre. Some reports also indicate that the sound was heard as far as 1200 miles away. These observations were analysed and interpreted along with those collected for other earthquakes in India during the past one and a quarter centuries and the results published.

(*c*) Studies were also made of the seismic seiches due to the Great Assam earthquake of 1950 observed prominently near about the outermost limit of the felt area in Central Burma, South West Bengal, North Bihar and East Uttar Pradesh. The results were used for a comparative study of the 1950 Assam Earthquake and the Lisbon Earthquake of 1755.

3. —

Research Work — Theory and applied Seismology, Seismologic Geography

(*a*) Development of seismological instruments and equipment like time-marking clocks, driving clocks, recorders, etc. was continued. Some more Wood-Anderson and Milne-Shaw type instruments were constructed. A few of the former were installed in the observatories opened during the period.

(*b*) The seismograms of the Great Assam earthquake of 1950 and of a large number of aftershocks from Indian stations and selected Extra-Indian stations were analysed with all the available

data. Velocities of the seismic waves and thicknesses of the crustal layers in North-East India have been obtained as follows :

P	=	7.91	km/sec.
P*	=	6.55	»
Pg	=	5.58	»
S	=	4.46	»
S*	=	3.85	»
Sg	=	3.43	»

Thickness of the Granitic layer = 25 kms.
Thickness of the Basaltic layer = 21 kms.

(*c*) A number of papers on other aspects of the subject has been compiled and published by the Central Board of Geophysics, the National Committee in India for the International Union of Geodesy and Geophysics. A list of these papers is given in the section on Bibliography.

(*d*) The following investigations in Engineering Seismology were carried out at the Central Water and Power Research Station at Poona.

(i) *Studies on local seismicity of the proposed Kosi Dam Site in Nepal.* — With a view to study the geological instability associated with the basement structure and the effect of other physical phenomena, such as flood intensity etc., near the dam site, a comprehensive study of local shocks recorded by a Benioff Vertical Seismograph in operation at the Chatra Seismological Observatory (7 kilometers downstream of the Kosi High Dam Site) was undertaken. It was seen that the Benioff Seismograph recorded a large number of local shocks indicative of the inherent instability associated with this region which is wellknown for the occurrence of earthquakes of magnitude 8 and above. The results of investigations have also revealed that a change of load due to a change of flood intensity releases a large number of local shocks of minute intensity recorded by the sensitive Benioff Seismograph. It was found that both during rising and falling phases of flood, the frequency of swarms of earthquake increased suddenly, indicating that it is the change of load and not the absolute value of the load which is responsible for this triggering off action. Due to the absence of any other seismological observatory near the dam site, the exact position of the epicentres could not be fixed but even the limited data showed that the frequency of a number of shocks shot up after an epicentral distance of 50 kilometers which is roughly the distance of the main Himalayan boundary fault from the Chatra Observatory, indicating (though not conclusively) that these swarms might have been originated near the zone of faulting. A few shocks originating close to the dam site, within a distance of 25 kilometers, were also recorded, but the zones of instability associated with these shocks could not be delineated due to the absence of other observatories.

(ii) *Study of prevalent spectrum of sites.* — With a view to study the prevalent seismic spectrum of the Kosi Dam Site, a good number of local shocks was analysed in their different prominent phases to assess the consistency of existence of any significant prevalent

spectrum. Analysis of nearly 30 earthquakes reveals the probability of existence of mean prevalent spectrum which does not seem to differ significantly in their different phases. A mean value of 0.32 sec. has been assessed as the mean prevalent spectrum of the site for Chatra Seismological Observatory which is situated on a sandstone hillock of recent origin. The value found here is in good accord with similar ones found by Gutenberg in California for similarly less compacted formations. In order to assess the amount of transmitted energy from the basement rock to the structure, assessments have been made of the possible range of free period of structure as may be existing during earthquakes in those regions on the lines of Waldorf and others of U. S. Bureau of Reclamation. This study supports the view that for these high structures considerable coupling will be available amongst various components participating in the dynamic action during earthquakes. These studies are however of a preliminary nature.

4. —

Summary of earthquake activity in India and neighbourhood during 1951-53.

During the period under review (1951-53) 242 shocks having their origin in India and neighbourhood were recorded at the Indian observatories. Of these only three shocks occurring near Lhasa (Tibet) had magnitude between 7 and 7½, 29 were moderately strong and the rest of light intensity. 46 shocks were felt in some parts of India.

The shock of 29th August 1953 occurring in the extreme north of Uttar Pradesh near the border of Nepal, was felt over a wide area in Uttar Pradesh, Bihar, Madhya Pradesh and East of Punjab.

5. —

Bibliography of articles and reports published

The seismological data of the seismograph stations at Bombay, Calcutta, Chatra, Colombo, Dehra Dun, Hyderabad, Kodaikanal, Madras, New Delhi and Poona were collected and edited at the Headquarters of the organisation and published with the data from Shillong, in the India Meteorological Department Seismological Bulletin in quarterly issues for 1943, July-September and 1944, January-March, and monthly issues for May 1950 to December 1951.

The manuscripts of the following members were got ready for issue — January 1952 to July 1953 :

The monthly seismological bulletin also includes from time to time reports from Voluntary Observers of the effects of felt earthquakes.

Publications

1. — MUKHERJEE (S. M.), « Landslides and sounds due to earthquakes in relation to the upper atmosphere, part I ». *Indian Journal of Meteorology*, vol. 3, n° 4, pp. 1-18, October, 1952.

2. — TANDON (A. N.), « Earthquakes ». *Indian Journal of Meteorology*, vol. 3, n° 1, January, 1952.

3. — TANDON (A. N.), « Earthquakes in Assam and neighbourhood from August 15, 1950 to April 1951 » (under publication in *Indian Journal of Meteorology*).

4. — PODDAR (M. C.), The Assam Earthquake of 15th August, 1950. *Indian Minerals*, vol. 4, n° 4.

5. — GOPAL (V.), A note on the investigations into the recent earthquake shocks in the Kottyam districts, Travancore-Cochin State. Published by the *Geological Survey of India*.

6. — MEHTA (B. F.), Report on Earth Tremors felt near Phaltan, North Satara District, Bombay. Published by the *Geological Survey of India*.

6. —

Papers on the Great Assam earthquake of August 15, 1950, compiled by the Central Board of Geophysics (Publication N° 1 of the Central Board of Geophysics) :

a) BANERJI (S. K.), The origin and the nature of the disturbance produced by the Assam Earthquake of August 15, 1950 and its after-shocks.

b) GULATEE (B. L.), The Geodetic and Geophysical Aspects of the Earthquakes in Assam.

c) PRAMANIK (S. K.) and MUKHERJEE (S. M.), The Assam Earthquake of 1950.

d) RAY (S.), Isoseismals for the great Assam Earthquake of 1950.

e) PODDAR (Shri M. C.), A short Note on the Assam Earthquake of August 15, 1950.

f) CORPS (E. V.), The Assam Earthquake of 15th August, 1950 as experienced at Digboi, Upper Assam.

g) BOILEAU (V. H.)., The Assam Earthquake of 15th August, 1950 - Results of the preliminary Geological Investigations.

h) MATHUR (L. P.), The Assam Earthquake of 15th August, 1950. - A short note on factual observations.

i) SEIGNIOR (Capt. C.H.T.), The Assam Earthquake.

j) GARG (G. R.), The Earthquake of August 15 and its effect on the Topography, the Regimes of the Rivers in North-East Assam, and Damage to Roads.

k) DUTT (G. N.), Damage caused by Earthquake of the 15th August, 1950 in Assam.

l) SOHONI (V. V.), The Great Assam Earthquake of 15th August, 1950.

m) TANDON (A. N.), The Very Great Earthquake of August 15, 1950.

n) MALURKAR (S. I.), The Great Earthquake on Assam Border of August 15, 1950.

o) TILLOTSON (Ernest), The Great Assam Earthquake of August 15, 1950.

p) KINGDON-WARD (Capt. F.), Notes on the Assam Earthquake.

q) GEE (E. P.), The Assam Earthquake of 1950.

r) AKIMA (T.), On dispersion curves of surface waves from the Great Assam Earthquake of August 15, 1950.

INDONESIE

NATIONAL REPORT ON THE SEISMOLOGICAL ACTIVITIES IN INDONESIA 1951-1953

Seismological Department of the Meteorological and Geophysical Service

Observatories

Djakarta Long. = 106° 50' E — Lat. — 06° 11' S. h = 8 m
Foundation — River Quarternary
Instruments — Wiechert Z comp. 1300 kg
Wiechert N and E comp. 1000 kg.

Bandung Long. = 107° 39' E — Lat. = 06° 54' S, h = 726 m
Foundation — Quarternary volcanics
Instruments — Wiechert N and E comp. 1000 kg.

During the last months of 1953 a set of Sprengnether seismographs has been installed at the Astronomical Observatory of Lembang. During the months of December 1953 and January 1954 there were some serious difficulties in adjusting the instruments because of the manyfold power cut offs. Very probably, however, this new station will registrate continuously from Mar. 1, 1954 onwards.

Lembang Long. = 107° 37' E — Lat. = 06° 50' S, h = 1295 m
Foundation — Quarternary volcanics
Instruments — Sprengnether Z comp. T = 1.7 sec.
Sprengnether N and E comp. T = ± 15.0 sec.

Macroseismic inquiries

During the years 1951-1953 the pre-war totals of 1500-2000 forms yearly send to the Meteorological and Geophysical Service concerning about 450 earthquakes have not been reached. The totals for the years 1950-1953 were respectively

	no of earthquakes	no of reports
1950	149	767
1951	109	476
1952	99	333
1953	99	590

These numbers, however, have been improved beginning with Jan. 1st 1954. New forms have been drafted and the new network of voluntary reporters now amount to more than 3000 divided into 2000 on the Isle of Java and more than 1000 in the outer provinces. The number of reports and earthquakes for the month of January 1954 are respectively 234 and 21.

The old intensity scale of the pre-war Royal Magnetic Observatory, Batavia, adapted to the living conditions in Indonesia is still in use. In the description of the macroseismic reports by the Meteorological & Geophysical Service this scale is transferred in that of Rossi-Forel.

Seismological Bulletins

Bulletins of the Djakarta and Bandung records were issued each third month during the years 1951 and 1952, each second month in 1953. Up till September 1952 the seismograms have been read by Mr. W. G. Thesingh, from October 1952 onwards by Dr. A. R. Ritsema.

Beginning with January 1954 the Bulletins do show also the direction of first movement in transversal waves and in reflected long longitudinal and transversal waves. These data appeared to be of some use in the epicentre determination of single earthquakes. For all longitudinal waves as usual the symbols c for compression and d for dilatation are used.

For transversal waves the symbols r and l have been introduced respectively for a first movement to the right as seen from the epicentre and a first movement to the left.

A bulletin of the earthquakes having taken place in the Indonesian Archipelago during the years 1950-1953 is in preparation. The last one of this series for the year 1941 (Serie A no. 44) has been prepared by *Prof. Dr. H. P. Berlage* in the year 1948. Dating from 1954 onward a yearly publication in this series has been planned.

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RITSEMA (A. R.), Some new data about earthquake movements at great depth in the Indonesian Archipelago. *Indonesian Journ., f. Nat. Sci.*, 1953, pp. 34-40.

— Further evidence of a discontinuity at about 130 km below the earth's surface. *J. Sci. Research Indonesia*, vol. II, pp. 10-11, 1953.

— New seismicity maps of the Banda Sea. *J. Sci. Research Indonesia*, vol. II, pp. 48-54, 1953.

— The Seismicity of the Sunda Arc in space and time. *Proc. Pac. Sci. Congress*, Manilla 1953.

— A statistical study of the seismicity of the earth.
a) Tangential stresses in the earth's crust and below.
b) Discontinuities and the distribution of earthquake foci in depth.
Bull. Sci. Res. Indonesia, n° 19 (in print.).

— The sense of the principal shearing stresses in the Tonga-Kermadec salient (in preparation).

— The mechanism in the focus of the Hindu Kush earthquakes (in preparation).

— A macroseismic study of some earthquakes felt at the Isle of Java (in preparation).

Projects for the future

The installation of some 15 small seismographs with mechanical registration throughout the archipelago is planned. The deliverance of the instruments and the set up of them will take some time however. It is hoped that at the end of 1957 Indonesia will be covered by 4 main stations at Djakarta, Lembang, Medan and Amboina with Sprengnethers and/or Wiecherts of 1000 and 1300 kg and by 15 secondary stations equipped with smaller seismographs at Kotaradja, Sibolga, Padang, Benkulen (all Isle of Sumatra), Sukabumi, Tjilatjap, Malang (Isle of Java), Denpasar (Bali), Bima (Sumbawa), Kupang (Timor), Banda Neira, Makassar, Menado (both Isle of Celebes) and Ternate (Isle of Halmaheira).

It is not yet known if the smaller seismographs of the secondary stations will be all of the same type.

The Volcanological Survey of Indonesia now dispose of 5 new short-period Sprengnether' sets and 3 Askania Galitzin-Wilip instruments, not yet set up.

It is the meaning of the Volcanological Survey to use these instruments at the flanks of the most dangerous volcanoes of the archipelago. If installed an agreement between the two Services comes into action, ensuring that the seismograms can be used for the Bulletins of the Seismological Department of the Meteorological & Geophysical Service at Djakarta.

Djakarta, March 1954.

IRELAND

REPORT OF WORK ON SEISMOLOGY AND PHYSICS OF THE INTERIOR OF THE EARTH 1951-1953

The only Seismological Observatory is that at *Rathfarnham Castle, Dublin.* At present there are three seismographs recording regularly. During the period 1951-1953 changes were made to improve the records, so that the present equipment is as follows :

(1) O'Leary Seismograph, Mass 1780 kgs, Period 16 secs, Magnification 150, Damping ratio 3-1, Paper speed 17 mm. per min.

(2) Short Period Vertical, Seismograph period 1.2 secs, Galvanometer period 0.2 secs, Critical Damping, Paper speed 30 mm. per min.

(3) Horizontal Pendulum, Seismograph period 10 secs, Galvanometer period 10 secs. Critical damping approximately, Paper speed 30 mm. per min.

Equipment for the timing and recording of quarry explosions is available and large explosions at a distance of 28 miles have been

well recorded under suitably quiet conditions. Preliminary estimates of the velocities through the intervening rocks have been made.

One small earthquake was felt in this country during the period 1951-1953. It was on Jan. 11 th. 1951 at 01 50 34 (G.M.T.). It was recorded at Rathfarnham and reports were collected from the area. The epicentre was near 53 N. 5.5 W. and it was widely felt in East and South East Ireland. The intensity was IV.

The fault planes of some epicentres are being investigated by the Byerly Hodgson method and with the use of the extended distance tables of Hodgson. Microseisms are measured four times daily at Rathfarnham and a fast recorder is being installed to record with increased amplification. A full investigation is planned. This project and the measuring of velocities from quarry explosions are being carried out in cooperation with the School of Cosmic Physics.

Publications :

HEELAN (P. A.), On the Theory of Head Waves. *Geophysics*, vol. XVIII. n° 4, 1953.

INGRAM (R. E.), Vibration Angle of S-Wave. *Bull. S.S.A.*, vol. 43, n° 2, 1953.

HEELAN (P. A.), Radiation from a Cylindrical Source of Finite Length. *Geophysics*, vol. XVIII, n° 3.

ISRAEL

RECHERCHES SÉISMOLOGIQUES EN ISRAEL

En moyenne, quatre faibles séismes se produisent chaque année en Israël. Environ tous les trois ans, deux de ceux-ci peuvent causer de légers dommages. En outre, des tremblements de terre destructeurs ébranlent le pays une fois en des dizaines d'années. Ils se reproduisent dans les mêmes sites une fois en quelques siècles. C'est pour cette raison que les habitants ne considèrent pas ce désastre comme propre à leur pays et c'est aussi pourquoi la recherche séismologique fut semblable, jusqu'à ces dernières années, aux études faites dans les anciennes archives, études qui ont d'ailleurs servi de base à celles de la physique pure. Cette étude a été faite par des savants étrangers tels que *F. de Montessus de Ballore. A. Sieberg, B. Willis, Gutenberg* et *Richter*, etc.

Dans le jeune Etat d'Israël, le nouveau régime a apporté un changement des valeurs dans la façon de vivre de la population. La reconstruction nationale suscite de nombreux projets qui donnent lieu à des grands travaux, dans tous les domaines : habitat, irrigation, industrie, exploitation du sol — toutes choses qui stimulent les recherches géologiques et géophysiques. C'est ainsi que le Département « Tahal », qui joue le rôle des « Eaux et Forêts en France, établit, depuis 1950, les projets d'irrigation en tenant compte des recherches séismiques. De plus en plus, en Israël, se fait sentir la nécessité de connaître à fond l'état séismique du pays. Des liens de

plus en plus étroits se sont établis entre Israël d'une part, le Bureau Central de Séismologie de Strasbourg, l'U.S. Coast & Geodetic Survey (Washington, D. C.), etc., etc., d'autre part.

La création, cette année, de deux observatoires, a introduit Israël dans le cadre de la recherche séismologique internationale.

Le terrible tremblement de terre de 1927, qui causa de grands désastres en Transjordanie et en Palestine, amena le Gouvernement mandataire à faire des recherches sur la séismicité du pays. Celui-ci fit appel au fameux Baily Willis. Le géologue anglais Blake soutint Willis et eut l'idée de créer des stations séismologiques. Il s'adressa, en mars 1928, au gouvernement anglais et lui demanda l'acquisition de 4 séismographes pour les installer à Jérusalem, Jéricho, Naplouse et Safed. Mais le gouvernement ne donna pas suite à cette demande.

Les événements passés, les blessures pansées, le problème des observatoires tomba dans l'oubli. Israël rétabli, l'idée fut reprise, non sous la pression de terribles tremblements de terre comme celui de 1927, mais afin de prévenir une future catastrophe.

Beno Gutenberg, président de l'Association Séismologique de l'U.G.G.I., visita le pays en 1951. Il s'adressa à l'Unesco et proposa de se charger de l'installation des observatoires. Les désastreux tremblements de terre dans les îles Ioniennes et de Chypre (août-septembre 1953) en accélérèrent la réalisation. On craignit en effet que la catastrophe ne s'étendît sur tous les pays du Moyen Orient.

Les détails du sinistre donnés par la presse alertèrent l'opinion publique.

La 5eAssemblée Générale de l'Unesco, tenue à Florence, vota dans son budget général de 2.300.000 dollars une aide technique aux pays où s'avérait nécessaire l'installation ou le perfectionnement d'observatoires (Israël, Turquie, Egypte, Liban, etc.).

Le but de l'Unesco était que la recherche séismologique se fasse en collaboration entre les pays de l'Est de la Méditerranée.

En octobre 1953, Israël reçut deux séismographes, construits à Pasadena, sous la surveillance de Gutenberg, avec tout l'équipement nécessaire.

L'Unesco accorda une subvention à l'ingénieur *C. Lomnitz,* qui partit en Californie, à l'Institute of Technology (C.I.T.) pour se perfectionner dans les études pratiques de la séismologie, auprès de Gutenberg.

En octobre 1953, le séismologue *Frank Press,* de l'Université de Colombia, fut envoyé en Israël pour installer les observatoires. Fin décembre 1953, les séismographes commencèrent déjà à fonctionner régulièrement à Jérusalem et à Safed (Galilée).

Ci-dessous les coordonnées :

Données	*Jérusalem*	*Safed*
Latitude	31° 46 9' N	32° 57 6' N
Longitude	35° 13 2' E	35° 29 7' E
Hauteur	790 m	800 m
Sous-sol	Calcaire	marne - craie

Les séismographes verticaux Benioff à longue et courte période furent installés dans les caves des laboratoires nationaux de physique

sous l'égide du Conseil Scientifique d'Israël, à Jérusalem et à Safed. Dans ces caves, il y a assez de place pour installer encore 3 séismographes.

Les instruments en question révèlent les mouvements verticaux les plus infimes du terrain et sont enregistrés par voie photogalvanométrique sur un ruban de 3 mm., à l'aide d'un système chronométrique standard (Greenwich) avec une précision qui atteint jusqu' au dixième de seconde. Ils sont d'une sensibilité extrême. Ces instruments enregistrent chaque jour tous les chocs régionaux et les importants séismes mondiaux.

La lecture des séismogrammes donne la distance, la profondeur, la magnitude, l'épicentre, etc.

Des instruments complémentaires, type Galitzine, mais plus perfectionnés, sont en construction dans les Laboratoires nationaux de Physique. Ces séismomètres rendront possibles des définitions fondamentales en composantes horizontales.

La station de Safed est d'une sensibilité supérieure à celle de Jérusalem, mais son équipement est plus modeste. Le travail scientifique essentiel se fait à Jérusalem.

Le nombre de séismes enregistrés est d'une centaine par mois. Ils viennent pour la plupart de loin, bien qu'au même moment, à l'est de la Méditerranée, règne une certaine agitation à cause de répliques provenant des graves tremblements de terre survenus en Grèce et à Chypre, l'année dernière.

Les observatoires israéliens fonctionnent comme une Institution gouvernementale, semblable aux services météorologiques, et sont en connection avec le réseau international de séismologie.

Afin d'améliorer le travail quotidien et sa planification, un comité a été élu parmi les hommes de science des Laboratoires nationaux de Physique, l'Institut Weizmann, l'Institut Géologique et le Service Météorologique. Ce dernier a l'intention d'élargir le cadre de ses observations dans le domaine de la prévision du temps et étudiera les microséismes.

Toutes les deux semaines, un bulletin préliminaire est envoyé par la voie la plus rapide à toutes les stations centrales et importantes d'Europe et d'Amérique. La demande incessante de ce bulletin témoigne de l'importance des observatoires israéliens dans le réseau international et sert tout particulièrement dans la définition de l'épicentre. Maintenant déjà, ces bulletins sont envoyés à 24 stations, dans 17 pays. Un bulletin plus complet sera envoyé par la suite, une ou deux fois par an.

Grâce à l'agrandissement extraordinaire de nos enregistrements et malgré leur nombre limité, beaucoup mieux que dans les meilleures stations américaines, sont enregistrés des séismes lointains.

Nos stations aspirent à une recherche non pas seulement théorique, mais aussi pratique.

En dehors de la recherche instrumentale, nous faisons des études macroséismologiques sur une grande échelle : partout ailleurs on ne fait des recherches macroséismologiques que dans le cas d'un tremblement de terre destructeur.

Les colonies collectivistes agricoles israéliennes (kibboutsim), où vit la plus grande partie de la population campagnarde, sont d'une

grande aide dans ce domaine. Le niveau culturel élevé de nos paysans — niveau qu'on ne rencontre nulle part ailleurs dans le monde parmi les populations rurales — permet de compter sur eux pour informer des séismes légers.

L'étude du séisme du 10 septembre 1953 — qui n'a pas causé de dommages — a cependant autant de valeur que celle d'un tremblement de terre grave.

Nous pouvons en conclure qu'il ne faut pas mettre l'accent sur les seules recherches instrumentales, car même dans les pays les mieux équipés, elle n'est pas encore absolument au point.

L'expérience nous a, en effet, appris que sans l'étude minutieuse des séismes, tant légers que graves, il est impossible d'accomplir une sérieuse recherche séismologique, d'autant plus que nos observatoires en sont encore au stade de tâtonnement.

L'étude nous permet de constater dès maintenant que les perturbations séismiques se déroulent dans une région séismique dont Israël fait partie, même s'il semble que ce pays soit en dehors de la zone orogénique voisine.

C'est pour cette raison que l'activité séismique paraît plus vive au nord qu'au sud, et aussi probablement à cause des répliques qui se produisent actuellement en Grèce et à Chypre.

Bien que le réseau macroséismologique israélien soit très serré (plus de 400 observateurs), il ne nous satisfait pas au point de vue de la répartition géographique. La frontière qui « étrangle » Israël entre ses voisins arabes n'est pas faite pour stimuler la recherche macrosismique parfaite. A ce point de vue, le régime mandataire nous donnait des possibilités — difficilement, toutefois, même alors — de pousser nos études simultanément des deux côtés du Jourdain.

En ce qui concerne la recherche séismologique elle-même, les séismographes n'ayant commencé à fonctionner chez nous que depuis 1954, nous ne notons pas dans notre liste bibliographique ci-jointe le bulletin bi-mensuel sus-mentionné qui paraît régulièrement depuis la fondation des observatoires. Des études se trouvent également sous presse.

La liste ci-jointe désigne : 1° un travail de compilation donnant un catalogue abrégé des séismes éprouvés dans le pays depuis l'ère chrétienne; — 2° une étude analytique de la séismicité au Levant depuis l'époque biblique; — 3° la description des chocs ressentis au cours de ces trois dernières années (1951 à 1953).

L'étude séismologique en Israël, au cours de la période sus-mentionnée, a abouti à une cartothèque contenant la documentation séismique que l'on trouve dans la vaste littérature palestinologique.

Les catalogues publiés jusqu'à nos jours ont presque totalement négligé la documentation en langue hébraïque et pourtant le nombre de documents en hébreu est presque équivalent à celui des documents dans les autres langues anciennes (araméen, arabe, grec, latin, etc...) et modernes.

Les renseignements contenus dans la cartothèque sont à la disposition de ceux qui s'y intéressent.

Dans le domaine de la Physique de l'Intérieur de la Terre, nous n'en sommes encore qu'à nos débuts. Si nous ne nous trompons, aucune recherche importante n'a encore été publiée jusqu'à présent.

Ces dernières années, toutefois, l'Armée, les Sociétés de Pétrole et de Recherche de l'Eau et en particulier l'Institut Weizmann, ont commencé à faire des études dans des buts pratiques, qui n'ont pas encore été rendues publiques.

Ci-dessous, la liste des Rapports intérieurs, presque tous faits par l'Institut Weizmann (Département des Mathématiques Appliquées) :

PROF. PEKERIS : Geophysical Survey of Southern Coastal Plain

1) (Wadi Sukreir - Gedera). Report E 1.
2) Migdal Gad - Faluja - Gat. Report 133.
3) Seismic Refraction Profile near Gal-On. B 1.
   Geophysical Survey of Coastal Plain. Yibna - Ramle.
4) Seismic Survey near Zarnuga. F 1.
5) Geophysical Survey (Natanya). H I.
   Geophysical Survey of Haifa Bay Area.
6) Geophysical Survey (Beit Dagon - Lydda). G I.
7) Essai pour trouver l'épaisseur des sédiments recouvrant la première couche de l'anticlinal de Kurnub.

Bibliographie :

AMIRAN (D. H.), A Revised Earthquake - Catalogue of Palestine; *Israel Exploration Journal,* vol. I, n° 4, pp. 223-246; vol. II, n° 1, pp. 48-65, Jerusalem, 1950-1952.

— Le centre séismique de Lod (Lydda) et la forme en genou de la côte de Jaffa. *Erets-Israël I,* pp. 173-177, Jérusalem, 1951 (en hébreu)

SHALEM (N.), La Séismicité au Levant. *Bulletin of the Research Council of Israel,* vol. II, June 1952, n° 1, pp. 1-15.

— Le Séisme du 31 janvier 1951. *Bull. Res. Counc. of Israel,* vol. II. June 1952, n° 1, pp. 15-16.

— On the Tremor of 28.12.1952 in the Galilee and Carmel areas. *Bull. Res. Counc. of Israel,* vol. II, March 1953, n° 4, p. 438.

— The Tremor of 10th September 1953. *Bull. Res. Counc. of Israel,* vol. III, December 1953, n° 3, p. 266.

— Le tremblement de Terre du 10 Septembre 1953. *Nature et Pays,* vol. X, fasc. 9, Décembre 1953, pp. 472-477; vol. X, fasc. 10, pp. 559-566. Avec Addendum : Les secousses en Palestine depuis le 31. 1. 1951 jusqu'au 17.2.1954 (en hébreu). *Ecole Technique Supérieure d'Israël.*

IRMAY (S.), On the dynamic behaviour of a generalized homogeneous isotropic linear rheological body. (Subject in the field of elasticity.) Publié en extrait dans : *Proceedings of the 8th International Congress on Theoretical and Applied Mechanics* Istanbul 1953, et aussi dans le *Bulletin of the Research Council of Israel,* vol. II, n° 1, June 1952. Le texte complet est sous presse au *Journal of Applied Mathematics and Mechanics, London.*

OLLENDORF (P.), Die Welt, die Vektoren. *Springer,* Wien 1951.

LINDMAN (M.) et ROSENBLATT (D. B.), The Radioactivity of the Hot Springs at Tiberias. *Science,* vol. 116 (1952), p. 689.

REINER (M.), On Volume Viscosity, *Bull. of the Research Council of Israel.* 3 (1953), pp. 67-71.

BRAUN, SCHŒNFELD-REINER et TRAUM, An Investigation into the Rheological Properties of Bitumen II., *Bull. of the Research Council of Israel*, 2 (1952), pp. 89-98.

N. B. — Nous rappelons dans cette liste les travaux pratiques sur l'étude des méthodes géophysiques, les questions traitant de la recherche des eaux souterraines, faits par les *Drs Loenberg, Stern*, etc...

U.G.G.I., Association de Séismologie - Israël.

N. SHALEM,

ITALIE

LA SISMOLOGIA IN ITALIA DAL 1951 AL 1954

RAPPORTO NAZIONALE

1. *Organizzazione.*

Nell'ultimo triennio, sono entrate in funzione in Italia tre nuove stazioni sismiche : a Tolmezzo, a Oropa e a Cuglieri (Sardegna). Inoltre la stazione sismica di Firenze (Arcetri) sta per essere trasferita a L'Aquila, presso il Gran Sasso d'Italia.

La stazione sismica di Tolmezzo è munita di sismografi a breve periodo, particolarmente indicati per la registrazione dei terremoti di vicina origine. Ad Oropa e a Cuglieri funzionano coppie di sismografi di tipo Wiechert, costruiti dall' Istituto Nazionale di Geofisica : uno per le componenti orizzontali (massa 200 Kg), l'altro per la componente verticale (massa 80 Kg).

Presso le stazioni di Tolmezzo, Pieve di Cadore, Salò, Oropa, Siena e Cuglieri funzionano inoltre coppie di fotoclinografi, atti al rilevamento di lente variazioni della verticale apparente.

Le Ricerche. — Daremo un breve riassunto delle principali ricerche intraprese e dei più notevoli risultati raggiunti.

2. *Terremoti di lontana origine. Struttura dell'Atlantico.*

Un lungo studio è stato dedicato al forte terremoto dello Hokkaido (Giappone) del 4 Marzo 1952. Già due contributi sono stati pubblicati su detto argomento : uno (18) inteso a determinare le coordinate ipocentrali del terremoto in questione, l'altro (19) dedicato alla determinazione dell'equazione della dromocrona più probabile delle onde P, valevole per distanze comprese tra 40° e 105°. In base a tale equazione vengono calcolati i tempi di tragitto e viene istituito un confronto con gli analoghi tempi calcolati da Jeffreys e Bullen, da Gutenberg e Richter e da Macelwane. I risultati ottenuti coincidono, entro i limiti degli errori sperimentali, con i tempi di Jeffreys e Bullen.

Un altro lavoro in corso su detto terremoto prova che si tratta di un sisma avvenuto in due tempi : inizialmente presso la superficie esterna della Terra, indi, a distanza di pochi secondi, al di sotto della crosta terrestre.

Continuando le ricerche sulla propagazione delle onde superficiali in corrispondenza del bacino Atlantico, si portano nuovi argomenti a favore della conclusione che fa il bacino Atlantico — da questo punto di vista — molto simile al bacino del Pacifico. Si determina poi, con un nuovo metodo, lo spessore medio della crosta in corrispondenza del bacino dell'Atlantico, pervenendo ad un valore di 19 Km ca. (8).

3) *Terremoto di origine vicina.*

Viene condotto un particolareggiato studio sul terremoto del Gran Sasso d'Italia del 5 Settembre 1950 (12). Precede un dettagliato esame delle notizie macrosismiche. Si calcola indi la magnitudo, l'energia, le coordinate ipocentrali e le velocità medie delle onde Pg, Pn, Sg, Sn, con relative dromocrone.

La profondità ipocentrale risulta di pochi chilometri.

L'ipocentro è molto prossimo ad una grande faglia (attiva) che da Nord di Amatrice va a Sud del Gran Sasso.

Lo spoglio delle reggistrazioni indica che la scossa è dovuta ad un sollevamento di strati ciò in accordo con i geologi, che ritengono l'orogenesi dell'Appennino ancora in fase positiva.

Un altro terremoto di origine vicina, sottoposto a studio, è stato quello che ha colpito la Sardegna settentrionale il 13 Novembre 1948 (20). La zona riveste particolare interesse, essendo stata ritenuta, in passato, pressoché asismica. Fra le cose più importanti da rilevare è un sensibile anticipo nella registrazione delle onde longitudinali e trasversali nei tragitti interessanti il Tirreno centrale, il che può essere interpretato con il supporre uno strato del granito di piccolissimo spessore. Sono state tracciate le dromocrone relative alle onde Pn, Sn, S* e M; ciò che ha consentito di rilevare le diversità di propagazione fra Sardegna ed Europa centrale e Sardegna — Italia centrale.

4) *Superficie di discontinuità; struttura della crosta terrestre.*

Un gruppo di lavori è dedicato alla crosta terrestre e alle sue superfici di discontinuità.

Mediante una misura della media velocità di gruppo delle onde L relativa al periodo di 20^s, si prova che tale velocità è notevolmente più elevata nel Mediterraneo centro-occidentale che nell'Europa, mentre nel Mare Adriatico diminuisce leggermente. Un tentativo di prospezione profonda nel Mediterraneo centro-occidentale e nell' Adriatico, mostra il notevole assottigliamento, rispetto all'Europa, dello spessore medio del primo strato della crosta terrestre (21).

Proseguendo lo studio del terremoto del Gran Sasso d'Italia del 5. IX. 1950, si perviene alla determinazione di alcune caratteristiche dell'Italia centrale. Rideterminata la profondità ipocentrale con il

metodo dell'angolo d'emergenza delle onde Pg, si valuta in 26 Km circa lo spessore dello strato del granito in corrispondenza del Gran Sasso d'Italia (13) : valore che ben si accorda con quelli precedentemente ottenuti per l'Appennino Tosco-Romagnolo e per la Garfagnana.

Un ulteriore lavoro (14), condotto con i dati raccolti in occasione del citato terremoto del Gran Sasso, ha permesso di confermare in 25 Km c. a. lo spessore medio dello strato del « granito » in corrispondenza dell'Italia centrale. Poiché lo strato susseguente è risultato di uno spessore di 35 Km c. a., in corrispondenza degli Appennini la superficie di Mohorovicic si troverebbe ad una profondità di 60 Km c. a. Inoltre, lo strato del « granito » risulterebbe assottigliarsi lentamente procedendo verso l'Italia meridionale (15).

In un lavoro di sintesi (5), si riassumono infine i principali risultati ottenuti da ricercatori italiani, nell'ultimo quindicennio, nello studio delle caratteristiche geologico-sismiche della penisola italiana, del Mediterraneo centrale e di una vasta zona comprendente la Svizzera settentrionale e il Württemberg, nonché di zone marginali atlantiche.

5) *Sismologia teorica (propagazione).*

Un lungo lavoro è dedicato al comportamento delle onde di Rayleigh in mezzi elastici e in mezzi che ammettono attrito interno. La trattazione è condotta con il metodo delle omografie vettoriali (1).

Fra i risultati raggiunti vanno citati i seguenti :

1. — La velocità di propagazione delle onde di Rayleigh in un mezzo firmo-elastico, dà un valore teoricamente infinito per periodi nulli, tende rapidamente, per periodi crescenti, al valore che le compete in mezzi puramente elastici, tanto più rapidamente quanto più prevale il modulo di rigidità μ sul coefficiente d'attrito interno equivoluminale.

2. — L'attrito interno determina una sensibile riduzione della componente verticale del moto : tanto maggiore quanto più piccoli sono il rapporto μ/μ' e il periodo proprio dell'onda.

Per onde originanti con grossi periodi, il mezzo si comporta come puramente elastico.

3. — Anche in un mezzo che ammette attrito interno, le onde del tipo Rayleigh costringono le particelle raggiunte su traiettorie ellittiche; però, a differenza di quanto avviene in un mezzo puramente elastico, tali traiettorie non sono riferite ai propri assi (fatta eccezione per i periodi infinitamente grandi o infinitamente piccoli).

4. — Contrariamente a quanto si verifica in un mezzo puramente elastico, l'osservazione prova che le onde di Rayleigh subiscono assorbimento da parte del mezzo : tale assorbimento, fortissimo per i periodi più piccoli, tende a decrescere rapidamente, per raggiungere il valore di circa $e^{-.0003}$ per periodi dell'ordine di 20^s. La nuova teoria prova che in un mezzo che ammette attrito interno (con un

rapporto $\mu/\mu' = 50\,\text{sec}^{-1}$, conforme alla media dei valori osservati) ciò è pienamente dimostrato: da un assorbimento elevatissimo per piccoli periodi, passando a periodi dell'ordine di 20^s e per $\mu/\mu' = 50$, il coefficiente d'assorbimento diviene dell'ordine di 0.0003, che è appunto quello generalmente osservato.

6) *Alcune caratteristiche fisiche del mantello e del nucleo terrestri.*

In un primo lavoro su questo argomento (22), viene stabilita una relazione fra la densità, la temperatura e la velocità delle onde longitudinali e trasversali relativa ad una particolare trasformazione adiabatica di un solido ideale. L'equazione, applicata al mantello della Terra conduce al risultato che la temperatura in prossimità del nucleo sarebbe circa 1,24 volte la temperatura alla profondità di 1000 Km, se la compressione dei materiali fosse avvenuta adiabaticamente.

Mediante la teoria di un solido ideale, si calcola (23 — con riferimento al mantello terrestre — il rapporto tra la dilatazione termica e il valore specifico a pressione costante, dai dati della velocità delle onde sismiche longitudinali e trasversali e della densità.

Tale rapporto decresce con l'aumentare della profondità, passando dal valore di $4{,}86.10^{-12}\,\text{g erg}^{-1}$ a 33 Km, al valore di $0{,}95.10^{-12}\,\text{g erg}^{-1}$ in prossimità del nucleo.

Viene calcolato nel mantello l'andamento adiabatico con la profondità del rapporto T/T33, essendo T33 la temperatura a 33 Km, e se ne deducono i valori approssimati del gradiente. L'analogo rapporto T/T 2900 nello strato E del nucleo, viene valutato con l'estensione della teoria.

In un terzo lavoro (24), viene stabilita, per via teorica, una relazione diretta fra la velocità delle onde elastiche e la densità di un solido isotropo ed omogeneo di tipo monoatomico, che si trovi ad una temperatura superiore alla temperatura di Debye.

Viene discussa l'applicabilità della relazione all'interno della Terra, e si istituisce un confronto con le velocità delle onde sismiche fornite da Jeffreys e le densità di Bullen. L'accordo tra la teoria e i dati geofisici risulta soddisfacente, sia per il mantello della Terra, che per il nucleo, a cui la teoria può essere estesa.

Mediante la teoria classica dei solidi vengono calcolate (26) le velocità delle onde elastiche, nello strato D dell'interno della Terra (parte inferiore del mantello), a pressione zero e alla temperatura della sommità dello strato. Si è otttenuta una velocità pari a 9,6 Km/sec. per le onde longitudinali e pari a 5,59 Km/sec. per le onde trasversali. Nessuno dei comuni silicati presenta velocità così elevate. Tale risultato è in buon accordo con le ricerche di Birch sull'argomento.

Da ultimo (27) si studiano alcuni particolari dell'andamento della velocità delle onde elastiche in uno strato solido, omogeneo, in equilibrio idrostatico, che si trovi ad una temperatura superiore alle temperature caratteristiche. Come applicazione, viene tentata una verifica, per il mantello terrestre, delle ipotesi in base alle quali è stato costruito il modello A di Bullen. La verifica, entro certi limiti, riesce positiva.

7) *Applicazioni della Sismologia e della clinometria.*

In un lavoro di geosismica (9), vengono esaminate alcune formule sulla velocità di trasmissione delle onde sismiche nel sottosuolo della media valle Padana, zona in cui l'autore ha avuto modo di compiere numerose campagne di prospezione, e l'influenza dell'anisotropia degli strati e delle loro vicende geologico-tettoniche sulle caratteristiche geometriche delle curve bradristocrone. Viene quindi proposto un sistema di calcolo delle superfici riflettenti, che permette la ricostruzione — sufficientemente esatta per la pratica — delle strutture, mediante i dati ottenuti dagli ordinari rilievi sismici a riflessione.

In un secondo lavoro sulla prospezione sismica (10), vengono applicati i principi della diffrazione alla riflessione delle onde sismiche. Si prova, fra l'altro, che in corrispondenza di discontinuità delle superfici riflettenti, le onde riflesse registrate non accusano brusche variazioni, come vorrebbero i principi dell'ottica geometrica, ma variano gradualmente, sia nell'ampiezza che negli angoli di fase : ne conseguono configurazioni per le riflessioni, tali da simulare delle strutture continue, all'apparenza di grande interesse per la prospezione mineraria. Vengono esposti gli accorgimenti che si debbono adottare nell'esecuzione di rilievi e nell'interpretazione geometrica degli stessi, allo scopo di non incorrere in ricostruzioni arbitrarie della tettonica degli strati riflettenti.

Sempre in tema di prospezione sismica, in un'altra ricerca (11) vengono discussi gli accorgimenti che si debbono adottare per rendere possibile l'indagine in zone ove le riflessioni, ottenute con la procedura normale, risultano scarse o insufficienti. In particolare, vengono discussi i metodi per aumentare l'energia delle onde immesse al suolo e quelli per diminuire le ampiezze dei disturbi in confronto alle ampiezze delle riflessioni utili. Infine viene discusso il sistema di registrazione col « trascinamento » delle onde.

Un ampio lavoro è dedicato alle osservazioni sismiche e clinografiche presso una grande diga di sbarramento per bacino idroelettrico (6). Tali osservazioni continuate presentano un interesse scientifico evidente per i nuovi elementi che si possono trarre circa il comportamento di una grande diga, nei confronti della roccia a cui è ancorata e delle spinte cui viene sottoposta dalla parte del bacino, e per aver messo in evidenza che molte cause perturbanti non hanno relazione alcuna con la scienza delle costruzioni, essendo di pretta origine geofisica (come i movimenti dei blocchi geodetici).

L'interesse pratico di tali ricerche è pure notevole, perché da una continua, pronta, sensibilissima azione di controllo, quale può essere quella esercitata da speciali sismografi e da fotoclinografi presso una grande diga, possono essere tempestivamente seguite eventuali, anche minime, flessioni e comunque evitati danni maggiori.

8) *Microsismi.*

Una lunga ricerca è dedicata all'origine dei microsismi, con particolare riguardo all'alto Adriatico (4). Si prova, ancora una volta, che rapide variazioni di pressione, collegate — oppure no — ai cicloni in transito sull'alto Adriatico e, in particolar modo, alla fase positiva

montante degli stessi, danno origine alla formazione di microsismi, tanto più sensibili quanto più prossima alla velocità delle onde libere del mare sottostante è la velocità dei disturbi microbarici. L'estensione di una teoria di Proudman sugli effetti della propagazione di variazioni di pressione sul mare consente di spiegare, in modo evidentissimo, il meccanismo del trasferimento d'energia dall'atmosfera al mare.

Si prova, fra l'altro, il ruolo di primaria importanza che giuoca la natura geologica del fondo del mare : e per la formazione e la propagazione dei microsismi a grandi distanze è infatti necessario che il fondo del mare consista di stratificazioni atte a ricevere e ad esaltare gli impulsi energetici che ad esso provengono attraverso l'acqua.

Un altro lavoro sui microsismi si riferisce al Mediterraneo occidentale (16). In esso viene confermato — che i microsismi di origine mediterranea non sono in diretta correlazione con i fronti, bensì vengono generati nelle zone, in mare aperto, interessate da nuclei di tendenza barometrica positiva.

9) *Onde guidate dall'astenosfera.*

Si prova (7), per la prima volta, che terremoti originanti al di sotto della crosta terrestre, e per profondità fino a 300 Km c. a., determinano la creazione di onde sismiche longitudinali e trasversali, che si propagano nello strato sferico così delimitato, costituente — com'è noto — l'*astenosfera.*

L'origine di queste onde va ricercata in quella parte dell'energia sismica che viene convogliata nel canale astenosferico, dove si verifica una flessione di velocità.

Il fenomeno, naturalmente, assume carattere generale, nel senso che strati dove si osserva flessione di velocità, possono guidare onde sismiche.

10) *Varie.*

In un lavoro (17), si danno ampie notizie della nuova stazione sismica di Messina, facente parte della rete sismologica dello Istituto Nazionale di Geofisica. Gli strumenti a registrazione meccanica (Wiechert 200, Wiechert 80 Kg) e quelli a registrazione fotografica (Galitzin e Sprengnether) fanno della stazione sismica di Messina uno dei caposaldi della rete sismologica italiana.

Un lavoro di sintesi (2) è dedicato alle interpretazioni geofisiche di misure geodetiche. Vengono riassunti i procedimenti che consentono una interpretazione geofisica delle misure geodetiche, specie per quanto concerne la *dilatazione,* la *rotazione,* la *distorsione* e la *deformazione principale.* Si accenna inoltre ai blocchi della crosta terrestre e alla realtà dei loro movimenti. Scopo del lavoro è quello di contribuire ad aprire un vasto campo di collaborazione ai geodeti ed ai geofisici : collaborazione che potrebbe condurre a frutti cospicui in una terra soggetta a bruschi e a lenti movimenti sensibili, quale è l'Italia.

Infine, sulla base della teoria classica dei solidi, viene dedotta (25) la dipendenza dalla densità della velocità delle onde elastiche di agitazione termica. Si valuta la pressione interna dovuta all'intera-

zione fra le particelle del solido, pervenendo ad un'equazione di stato valida per solidi isotropi di tipo monoatomico o per cristalli ionici. L'accordo della teoria con le misure di compressione effettuate da Bridgman e con i dati sismici, risulta verificato entro i limiti degli errori sperimentali.

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2. — CALOI (P.), « Interpretazioni geofisiche di misure geodetiche ». « *Annali di Geofisica* », IV (1951).
3. — « Effetti dell'attrito interno sulla velocità delle onde sismiche superficiali a brevissimo periodo ». « *Annali di Geofisica* », IV (1951).
4. — CALOI (P.), « Sull'origine dei microsismi con particolare riguardo all'alto Adriatico ». « *Annali di Geofisica* », IV (1951).
5. — CALOI (P.), « Struttura geologico-sismica dell'Europa centro-meridionale, dell'Italia e del Mediterraneo centro-occidentale, quale risulta da recenti ricerche compiute in Italia ». « *Annali di Geofisica* », V (1952).
6. — CALOI (P.), « Osservazioni sismiche e clinografiche presso grandi dighe di sbarramento ». « *Annali di Geofisica* », VI (1953).
7. — CALOI (P.), « Onde longitudinali e trasversali guidate dalla astencsfera ». *Rend. Accademia Naz. dei Lincei* (Classe Scienze fis, mat. e nat.), serie VIII, v. XV (1953).
8. — CALOI (P.) e MARCELLI (L.), « Onde superficiali attraverso il bacino dell'Atlantico ». « *Annali di Geofisica* », V (1952).
9. — CONTINI (C.), « Il calcolo delle superfici riflettenti nei rilievi sismici a riflessione ». « *Annali di Geofisica* », V (1952).
10. — CONTINI (C.), « La rifrazione nei rilievi sismici a riflessione ». « *Annali di Geofisica* », VI (1953).
11. — CONTINI (C.), « Appunti per la prospezione sismica delle zone con riflessioni scarse o insufficienti ». « *Annali di Geofisica* », VI (1953).
12. — DI FILIPPO (D.) e MARCELLI (L.), « Uno studio del terremoto del Gran Sasso d'Italia del 5 Settembre 1950 ». « *Annali di Geofisica* », IV (1951).
13. — DI FILIPPO (D.) e MARCELLI (L.), « Tempi di tragitto delle onde P* e spessore dello strato del granito nell'Italia centrale ». « *Annali di Geofisica* », IV (1951)
14. — DI FILIPPO (D.) e MARCELLI (L.), « Dromocrone per terremoti vicini e velocità delle onde sismiche nell'Italia centrale ». « *Annali di Geofisica* », V (1952).
15. — DI FILIPPO (D.) e MARCELLI (L.), « Struttura della crosta terrestre in corrispondenza dell'Italia centrale (Gran Sasso). « *Annali di Geofisica* », V (1952).
16. — GIORGI (M.) e ROSINI (E.), « Sull'origine dei microsismi del Mediterraneo ». « *Annali di Geofisica* », IV (1951).
17. — GIRLANDA (A.), « La stazione sismica di Messina ». « *Annali di Geofisica* », VI (1953).
18. — GIRLANDA (A.), « Il terremoto dell'Hokkaido del 4 Marzo 1952 ». « *Annali di Geofisica* », VI (1953).
19. — GIRLANDA (A.), « Il terremoto dell'Hokkaido del 4 Marzo 1952 ». Parte II. « *Annali di Geofisica* », VI (1953).

— MARCELLI (L.) e CALOI (P.), vedi n° 8.
— MARCELLI (L.) e DI FILIPPO (D.), vedi nn. 12, 13, 14 e 15.

20. — PERONACI (F.), « Il terremoto sardo del 13 Novembre 1948 ». « *Annali di Geofisica* », VI (1953).
— ROSINI (E.) et GIORGI (M.), vedi n° 16.

21. — VALLE (P. E.), « Sulla struttura della crosta terrestre nel Mediterraneo centro-occidentale e nell'Adriatico ». « *Annali di Geofisica* », IV (1951).

22. — VALLE (P. E.), « Sull'aumento di temperatura nel mantello della Terra per compressione adiabatica ». « *Annali di Geofisica* », IV (1951).

23. — VALLE (P. E.), « Sul gradiente adiabatico di temperatura nell'interno della Terra ». « *Annali di Geofisica* », V (1952).

24. — VALLE (P. E.), « Una relazione diretta fra la velocità delle onde elastiche e la densità nell'interno della Terra », V (1952).

25. — VALLE (P. E.), « Una equazione di stato per solidi ». « *Annali di Geofisica* », VI (1953)).

26. — VALLE (P. E.), « Sulle proprietà elastiche del mantello interno della Terra ». « *Annali di Geofisica* », VI (1953).

27. — VALLE (P. E.), « Sull'omogeneità e sullo stato di equilibrio del mantello interno della Terra ». « *Annali di Geofisica* », VII (1954).

Si è avuta poi l'abituale pubblicazione e distribuzione di Bollettini provvisori decadali e mensili da parte dell'Istituto Nazionale di Geofisica; bollettini mensili provvisori sono pure stati distribuiti dalle stazioni di Firenze (Ximeniano), Pavia, Prato e Trieste.

PIETRO CALOI.
Direttore d'Osservatorio.

JAPON

SEISMOLOGY AND PHYSICS OF THE INTERIOR OF THE EARTH IN JAPAN, 1951-1953

In the period covered by this report, Japan has advanced along the road to recovery from its devastation by war although the pace has as yet inevitably been slow in scientific investigation.

Part I. GENERAL.

1. Research Organizations

Little change has taken place in the organizations engaged in seismological research. Improvements were made gradually in the routine observation system of earthquakes under the Central Meteorological Observatory (C. M.O.), to which network have been added two new stations at Muroran, and Nara, where a set of strong motion seismographs have been installed while three stations — Asahikawa, Kasiwara and Uwazima — suspended their functions.

Research work is being performed as before by the members of this observatory as well as by those of the Earthquake Research Institute of Tokyo University. A new geophysical institute was established in Hokkaido University at Sapporo, and a chair of Geophysics was created at the Institute of Earth-Sciences, Nagoya University. The members of the Geophysical Institutes at Tokyo, Kyoto, and Tohoku Universities and those in the new institutes are engaged in investigation and in the education of special students in geophysics. Seismologists in other national universities are similarly active.

Names and positions of observatories and the instruments installed therein are tabulated in Appendix A of this report.

The Geographical Survey Institute and the Hydrographic Department continued their cooperation in cases of severe earthquakes in the surveys of topographical changes accompanying the earthquakes by means of precise geodetic works and soundings respectively.

Teams on seismic prospecting are working in the Geophysical Prospecting Division of the Geological Survey, Ministry of Commerce; and the Architecture Research Institute, Ministry of Construction, and in private companies engaged in geophysical exploration and mining.

The Section of Seismology of the National Committee for Geophysics cooperates as ever on an international basis in seismological research. The Seismological Society of Japan increased its activity, and held two general meetings a year, at which about 50 papers were read and symposia were held. The themes of the latter were ' the symbols of various phases of seismic waves ', ' microseisms ', ' surface waves', 'the structure of the earth's interior' and 'seismometers'.

2. Publications relating to Seismology

Results of seismometrical observations at stations under the C. M. O. are reported provisionally in the « Brief Report of Earthquakes » (in Japanese, monthly) and summarized in the « Seismological Bulletin of C.M.O. » which is now published monthly. The seismological bulletin of the Abuyama Observatory, Kyoto University was started in April, 1952. The Latitude Observatory publishes yearly the « Seismological Observations at Mizusawa », while the Osaka Meteorological Observatory publishes their bulletin irregularly.

Seismological papers are published in the magazines of various organizations and associations. The names of such publications are shown in Appendix B of this report with lists of articles and reports on seismology contained therein. A simple review of them will be given in Part II of this report.

3. Obituary

But before entering into this task, I must announce with great regret that we Japanese seismologists have lost our greatest pioneers. Professors A. Tanakadate and H. Nagaoka, who breathed their last on May 21, 1952 and Dec. 11, 1950 respectively. Needless to say that they were the most eminent founders of physical science in this country, but they had been up to their last day indefatigable investigators as well as the best leaders of geophysics in Japan, although

they were already of very advanced age (95 and 84 years respectively) (451, 448).

No less lamentable are the deaths of such young seismologists as Prof. Yanosuke Otsuka and Mr. Syôsaku Homma. Dr. Otsuka was a member of the Earthquake Research Institute, where he investigated geologically the phenomena of earthquakes and his investigation of the Cainozoic geology of Japan is highly esteemed in this country. He ended his days on Aug. 7, 1950 at the age of 47. On Oct. 23, 1953, the geophysical circle of Japan lost one of its most active and hopeful scholars — Mr. Homma. His great contribution to our science is clearly perceived in the quality, number and variety of his studies in the present period alone as reviewed in the following. He had been working in the C. M. O. Tokyo, and at the Matusiro Seismological Observatory.

Among the much-lamented victims of Fifth Kaiyô-maru of the Hydrographic Department, which was wrecked by the submarine eruption of the Myôzin-syô of Sept. 24, 1952, we find the names of Drs. Risaburô Tayama and Kiyosuke Kawada, who also contributed oceanological and geological papers on earthquakes (452-454).

Part II SEISMOLOGICAL INVESTIGATIONS

Those papers and reports published in 1951-53 amounted to as many as 450 and covered so wide a field that only the important items can be reviewed here.

Chapter I. *Investigations of Destructive Earthquakes, and Swarms of Minor Earthquakes.*

1.1 Major earthquakes with magnitudes M over 7 which originated in the vicinity of Japan in the period are tabulated in the following.

Table 1.

1951, III, 6.05 h. 12 m. 129° 3 E., 28° 3 N. h = 200 km. M = 7.
Felt on the Ryûkû islands and in Southern Kyûshû. Im = IV.

1951, IV, 17.04 h. 53 m. 138° 0 E., 31° 2 N. h = 470 km. M. = 7.
Though the Maximum intensity was only II, it was felt abnormally at parts of the Kwantô and Tôhoku districts and as far north as Sapporo ($\triangle$ = 1350 km.).

1951, X, 18. 17 h. 26 m. 142° 1 E, 41° 3 N. h = 40 km.
Felt in Hokkaidô, Tôhoku and most parts of the Kwantô district. Im = V. Some damage was caused at Hatinohe and vicinity.

1952, III, 4. 10 h. 23 m. 16. M = 8.1. (The Tokati-oki Earthquake)
143°.9 ± 0°. 1 E, 41°.8 ± 0°.04 N.
The largest earthquake in this period. Felt throughout Hokkaidô, Tôhoku, Kwantô and most parts of Tyûbu districts.
Maximum intensity was VI. Destructive tsunami was experienced at the south-eastern coast of Hokkaidô and the Sanriku coast.
815 houses were totally destroyed and 1324 partially destroyed, while 91 were washed out and 14 burnt. It took a toll of twenty-eight killed and 287 injured and five persons missing.

1952, III, 7. 16 h. 23 m. 136° 12'. ± 0'. 7 E, 36° 28'. 1 ± 0'. 6 N. h = 20 km.
Felt throughout the Tyûbu and a part of Kwantô, Kinki, Tyûgoku and Sikoku Districts, some damage was caused in Isikawa and Fukui prefectures (Im = V).

1952, III, 10.02 h. 04 m. 143° 5 E, 41° 7 N. h = 20 km. M = 7.
An aftershock of the Tokati-oki earthquake. Felt throughout Hokkaidô and most part of Tôhoku and Kwantô and some parts of the Tyûbu Districts.
Slight damage was caused in Hokkaidô and a slight tsunami was observed.

1952, V, 28. 16 h. 59 m. 135° 8 E, 35° 1 N. h = 370 km. M = 6.75-7.
Felt in Kwantô and parts of Tôhoku, Kinki and Tyûgoku districts and a part of Hokkaidô. Im = III.

1952, VIII, 18. 01 h. 10 m. 135° 48'.7 ± 0'. 6 E, 34° 26'. 9 ± 0'. 8 N. h = 70 km. M = 7.2 (The Yosino Earthquake).
Felt throughout Kinki, Tyûgoku and Sikokû and at parts Kwantô, Tôhoku and Kyûsyû districts. Im = V.
9 persons were killed and 139 injured. 20 dwelling houses were totally demolished while 26 houses were damaged badly and 278 houses slightly.

1953, XI, 26. 02 h. 49 m. 33 s. 141° 2 E, 34° 3 N. M 7.5 (Bôsô-oki Earthquake).
Felt throughout Kwantô, Tyûbu and Tôhoku districts and a part of the districts, Kinko, Sikoku and Hokkaidô districts.
It was severe (Im V) at Tomisaki and the Miyakezima Island and slight damage was caused. A tsunami 3 m high was observed at Tyôsi, it was 1.8 m. high at Tomisaki. But fortunately it was the time of low tide and no material damage was caused by this tsunami.
The most important ones among them were the earthquake of Mar. 4, 1952 originated off the coast of Tokati, Hokkaidô, and the Yosino earthquake of July 18, 1952 and the earthquake of Nov. 26, 1953 off the coast of Bôsô peninsula.

1.2 Results of special studies on these destructive earthquakes except the last and some of the previous period were published in this period.

The report on the Mikawa earthquake of Jan. 13, 1945 by the members of the C. M. O. was published in this period (182). It contains introductions, diaries of reconnaissance tours, and descriptions of damage on structures, crustal deformations, effects on the sea and subterranean water, sound and luminescent phenomena, precursing phenomena and aftershocks.

The studies of the Imaichi earthquake of Dec. 26, 1950 were reported in the last national report to the Brussels Conference, 1951. But several studies on this earthquake are also published in this period. Koshikawa (32) obtained the position of the hypocentre of the 2nd earthquake by the method of least squares at

36° 43'. 7 N; 139° 39'. 4 E; h. 14 — 18 km.,

and origin time, 25 : 23 h. 24 m. 53.8 s. (G.M.T.)
and the velocity of the p*; Vp* = 5.97 km/sec.

Aftershocks (33,420), geology and landslides (38) and crustal deformations (18) in the epicentral area and vicinity of this earthquake were also reported in addition to magnetic changes ascribable to the occurrence of this earthquake. Among these phenomena, the change in the precise levels measured by the staff of the Geographical Survey institute was noteworthy. Upheaval of about 30 cm was revealed in the epicentral tract while subsidence of minor amount was observed within the radius of 10 km from the epicentre. The possibility of ascribing the deformations to the movement of the superficial soil layer less than 10 m thick was already questioned in the last report to Brussels but no critical study of this fact has yet appeared.

1.3. In the Investigation of the Tokati-oki earthquake of March 4, 1952, were engaged the members of the C. M. O. and national Universities of Hokkaidô, Tôhoku and Tokyo, as well as of the Geological Survey, the Geographical Survey Institute and the Hydrographic Department. Not all the reports of these investigations have yet been published. The C. M. O. published a general report (223) of this earthquake, the main parts of which are reproduced in the monographs of the local Government of Hokkaidô. The latter contains the report of the disasters, and the records of the prompt measures taken, and permanent measures to be taken for the recovery from and prevention of seismic disasters. Kawasumi's report on the seismic and volcanic activities in this district with historical tables are also included.

T. Fukutomi (422) and others estimated the maximum accelerations of this earthquake at various points from the overturning of tombstones, and reported them with remarkable cracks observed in a badly shaken area.

M. Hayakawa (297) et al report their reconnaissance in the report of the Geological Survey, and Y. Kato and 3 collaborators (143) resurveyed the magnetic changes. Studies on the tsunami and the report on the effects on man-made structures were also published (350, 435, 436).

1.4 The Daisyozi-oki Earthquake of Mar. 7, 1952, which caused minor damage, was studied briefly by the members (232-235) of C.M.O. only and the Yosino earthquake of Juli 18, 1952 was also reported on by C. M. O. alone (247).

The earthquake off the coast of Bôsô peninsula on Nov. 26, 1953 caused only slight damage on land and no elaborate field investigations were made. Results of some studies on the tsunami, post-card queries and seismometrical investigations will be made in future.

A swarm of earthquakes in Wakayama prefecture renewed their activity recently, and a research of them was commenced in August 1952, under the cooperation of the Osaka Meteorological Observatory, the Earthquake Research Institute, and the Geophysical Institute of Kyoto University, and the first report was published in 1953 (266, 268-274).

It contains the observations instrumentally made at several temporal stations as well as the permanent Meteorological Stations, and observations of the inhabitants by unaided senses are also collected.

from which the distributions of epicentres are worked out and discussed. Tilt observations by means of water U-tube are also reported.

Swarms of earthquakes occurred in the vicinity of Lake Towada in March (340), and arround the Akan Volcano (222, 241), Hokkaidô in July of 1952. In the latter region conspicuous activity of minute earthquakes was also observed during a few days after the great Tokati-oki earthquake.

Chapter II. *Instrument Improvements in Seismic Observations.*

2.0 As it is generally the case with the exact sciences to be established upon positive quantitative facts, any improvement in seismometric instruments and methods of observation reflects progress in our seismology. Little by little, advance is made in this field in post war circumstances in Japan notwithstanding her financial and technical drawbacks especially in electronics technique.

2.1 The projet of the C.M.O. to improve the time accuracy in earthquake observations were reported to the Brussels Conference. The number of stations equipped with those instruments has increased from 5 to 9. The names of stations where installation took place in previous and present periods being Tokyo, Mito, Maebasi, Utunomiya, Nagoya and Sapporo, Sendai, Osaka, Hukuoka respectively. According to the detailed report by S. Suyehiro (163), the reformation consists of two steps, the one being a contrivance to regulate the revolution of recording drums, and the other the use of exact time marks derived from the JJY second signals astronomically controlled. The main part of the first contrivance is a conical pendulum with a frictional governor, whose motion is regulated by electromagnetic impulses given every second from a standard clock, which in turn is regulated by the JJY second signals.

A similar precision recording drum has been studied by C. Tsuboi and his collaborators for several years, while T. Hagiwara in the Earthquake Research Institute generated accurate alternating current of 50 cycles by means of a tuning fork of 1,000 cycles installed in a thermostat, and used it to drive synchronous motors for revolving the recording drums in the institute. Seismographs of galvanometric recording have gradually increased in the same institute, for which a fine optical recorder using 35 mm cine-film has been constructed.

2.2 The new long period seismograph designed by the members of the C. M. O. was reported to the Brussels Conference. A pair of these instruments is installed in a cave at the Matusiro Seismological Observatory. According to the detailed report (209). it is a horizontal pendulum of Zollner suspension with magnification of ca. 100 and period adjustable to 40 to 50 seconds. In order to overcome the friction a mass of 1,100 kg was used, the distance of its centre of gravity from the rotation axis and the moment of inertia being 45.3 cm and 3.7×10^9 c.g.s. respectively. But owing to the high sensitivity to tilting, the periods of these instruments have been shortened to about 30 sec. even at the centre of a large cave of this observatory. This instrument is provided with a magnetic damper and record is taken on a smoked paper.

Notwithstanding to this inconvenience, the record obtained

thereof is remarkably useful to the study of surface waves, and even the L waves of near earthquakes have been recorded clearly.

2.3 The achievements of a strong motion seismograph and a response computer by the Strong Motion Accelerograph Committee are also worthy of special notice (366). The committee was composed of the members of the Earthquake Research Institute and other engineers of Architecture. The former instrument is manufactured by the Akashi Instrument Works under the name « SMAC » Strong Motion Seismometer. It can record three components of the acceleration of earthquakes within the range 10-1,000 gals, the sensitivity being 25 gals/mm. The proper period of each pendulum is adjusted to 0.1 sec., and damping is provided by an air damper. The record is made by a fine sapphire point on a long sheet of stylus paper driven out by a mechanical clock, which is connected with a two way starter. This starter is composed of two contrivances, the one being a vertical motion seismograph which makes an electric circuit to start the clock work, and the other being a falling mass which directly unlocks the stopper. This instrument is designed with special precautions of foolproof and earthquake proof construction. Two sets of this instrument were presented by Japan to Chile and are now being used there.

2.4 The response computer (428) is an instrument to compute the response characteristics of a structure subjected to an earthquake acceleration. A galvanometer system is substituted for a structure with a definite period and damping, and the motion thereof responding to an electric current (which is made proportional to the acceleration of an earthquake) is recorded continuously. The speed of variation of the electric current is changed instead of using many galvanometers with different periods.

This instrument serves also as an analyser of the characteristics of earthquake motions. Contributions of these instruments to the design of earthquake proof construction as well as to pure seismology is to be hoped.

2.5 T. Akima's low-pass filter (72) which closely resembles the above instrument is improved with the use of an electromagnetic damper.

Another instrument with a somewhat similar idea was devised by T. Tomoda and K. Aki (337). It is a detector of the predominant period in quasistationary tremors. It is a kind of seismometer with a pendulum of the Wood-Anderson type, whose period is changed automatically step by step at regular intervals, by the application of a varied magnetic field to the soft iron bob of the pendulum. Well-defined resonance phenomena are observed in actual examples.

2.6 There have been made many devices and improvements in recording apparatus and methods, such as mechanical recording on smoked paper for electromagnetic seismographs (344), the use of magnetic tape recorder (347) and ink writer on glass cylinders, etc. (260, 325, 326).

The last two devices were made by C. Tsuboi and his collaborators, and are equipped with erasers and mechanisms which enable seismograms of certain magnitude alone to be retained.

Improvements on damping devices (313), writing pointers (334, 343) and precision revolving drums (310) are also reported.

2.7 G. Nishimura (124) and others made an instrument for seismic prospecting on a new principle of interest. The first impulses of artificial earthquake to two highly sensitive pick-ups of their design set up at a distance are so amplified that they immediately operate a flip-flop circuit to make and break a current. The duration of this current is measured by the number of high frequency electric ossillations during the interval and is indicated digitally by lighted neon lamps.

S. Miyamura (311, 375) et al studied methods of sending time signals and tele-recording of earthquakes by means of carrier waves through telephone-cables, while Z. Kawase (362) used a multiplier photo-tube instead of an electro-magnetic inductor for a transducer.

N. Den's improvement (363) of the amplifiers of prospecting instruments and K. Tazime's device (304) for field calibration of seismic instruments for prospecting are to be noted. Z. Suzuki and Den (319, 354) made a portable noise-level meter with resonators of 5, 10, 20, 30 and 40 cycles per second. Den (333) used also a reactance tube for obtaining a high inductance circuit up to tens of thousands of henries.

2.8 Theories and calibrations of seismometric instruments were also reported by many workers (200, 213, 215, 236). A team of seismologists under the leadership of K. Sagisaka (197) and S. Homma at the Matsusiro Observatory examined the effects of various parts of seismographs, such as the mass of helical spring (198) and the counter weight of vertical seismographs (214), and flat springs used at the rotation axis of a horizontal pendulum (196). They also gave notes on the measurement of small angles by the optical method (199) and on the effect of Galitzin seismographs on the initial recorded impulsions (170). A series of nomographs was also made by them for the determination of harmonic magnification factors for the same instrument (185).

Lastly C, Tsuboi and Tomoda's remark (317) on the optimum number of magnifying levers and Z. Suzuki's study (352) on air dampers showing the non-linear effect of the compression are to be noted.

Some notes and calibrations for seismographs in actual use are also reported.

Chapter III. *Problems of Pure Seismology.*

3.0. Among the numerous papers on pure seismology, noteworthy are those on the field theory of earthquakes and on the magnitude, frequency, and time-space distribution of earthquakes occurring in this country. Observations of surface waves are also to be noted. Travel time curves and the space distribution of first impulsions of earthquakes were discussed by comparatively few investigators.

3.1. Field Theory of Earthquakes.

The field theory of earthquakes by T. Matuzawa (110, 117) is the most interesting and concrete theory ever proposed on the cause of earthquakes. The working hypothesis is that the earthquake is

generated by a heat engine which makes a complete cycle in some 100 years. The energy of the earthquake is stored in the crust above the source in the form of strain energy, the original supply of which is the heat transported upward by the convection of magmatic substance. He inserted into this process of energy transformation a step of melting of subcrustal basalt at the source so that, according to him, the crust plays the role of piston while the basalt is the working substance which undergoes the solid-liquid transformation and plays the role of the water in a steam engine. The necessity of this working substance is clear because the necessary strain energy can only be supplied by an inconceivable temperature rise (ca. 100° C) if the thermal strain alone is to be considered. He also postulated that the earthquakes occur in seismic zones where the subcrustal convection of magma is possible, because the general heat flow in the crust cannot supply the necessary energy.

From these hypotheses he could well explain the cycle of great earthquakes, by a temperature rise of a mere 5° C at the source. This temperature rise is the result of the change in the melting point of the basalt corresponding to the pressure rise of 3×10^8 dyne/cm^2. He theoretically calculated the deformation of the surface granitic layer of 50 Km in thickness. If the crust is clamped at this circular boundary, the total strain energy stored up in the crust amounts to 8×10^{24} ergs, while the maximum shear is almost equal to the ultimate strength of the granitic substance. This strain energy at length is released by a sudden break-down near the boundary, so that the epicentre is not confined to a point but extends at times from the lower boundary of the crust up to the surface.

The recurrences of large aftershocks in short intervals are explained by him by the advance of melting of the super-heated basalt being facilitated by the release of the pressure at the source by the cracking in the first earthquake. The reviewer would like to point out that the recurrence of aftershock in this manner is possible only when the crack, which after releasing the initial strain of the crust and the pressure at the source, heals almost perfectly to enable the re-instoration of the strain energy of an amount comparable with that of the main earthquake within an interval of a few minutes or hours, unless the friction is as great as the strength of a continuous body.

He also gives some notes on the crustal deformations usually revealed in great earthquakes. The potential energy transferred within the epicentral region is, in his estimation, about 10 times of the strain energy released in the main earthquake. But his discussion on this point seems to be too short and obscure to clarify the problem.

3.2. Magnitudes of Earthquakes.

Problems on the magnitude of the earthquakes and allied items have been studied by many authors, and many papers of interest were published in the present period.

3.21. Results of H. Kawasumi's study (50) of many years were reported to the Brussels conference. Together with the report, the

papers read at the Pan-Pacific Science Congress, at Wellington, in 1949 on the relative frequency of earthquakes with respective magnitudes were published in this period (93, 94). According to these papers, he first obtained from the data of some 100 earthquakes the mean formulae for the attenuation with the epicentral distance of the intensity and the maximum amplitude of an earthquake, and used them to determine the intensity or the amplitude at the distance of 100 Km from the epicentre of an earthquake, and he used the former as an index of magnitude Mk of the earthquake. The relations between Mk and the amplitude at the same epicentral distance or the Richter-Gutenberg magnitude M were statistically determined. The magnitudes of destructive earthquakes in historical times and the major earthquakes in recent years were then determined. Statistics of smaller earthquakes observed at Hongo, Tokyo were theoretically discussed and an energy law was obtained on the occurrence of earthquakes. It showed that the frequency of occurrence, from a unit volume of a crustal layer in the Tokyo area, of an earthquake with a certain amplitude is inversely proportional to the square of the amplitude, i. e, the law of equipartition of energy holds. An identical law was also found for the major earthquakes in Japan and her vicinity. About 4,000 Japanese earthquakes in the last 60 years were also determined by him, the results of which were published in the Seismological Bulletins of the C. M. O. for 1950.

In the report to Brussels he inferred the number of earthquakes which have been experienced since historical times with respective intensities at any point in Japan. From these statistics he derived distributions of certain measures of earthquake danger and expectancies of maximum acceleration of earthquakes to be experienced in definite periods. These results were adopted in the building code and engineering regulations in this country and are also applied to the earthquake insurance.

3.22 C. Tsuboi (128) determined linear equations representing the relations between the magnitude of Japanese earthquakes as determined at Pasadena and the logarithms of its amplitude as observed at a station and the epicentral distance of the station (128). To say nothing of the inaccuracies arising from the smallness of the number of data and inevitable fluctuations of observed amplitudes, the linear equation cannot be applied to the observations made within 100 Km from the epicentre. It is also pointed out by R. Yosiyama that the difference of the magnitudes of the same earthquake as determined by Tsuboi's formula and from the observations at Pasadena shows a systematic trend with M.

In the second report (383), Tsuboi gave the result of his determination of the magnitudes of 735 Japanese earthquakes in the past 20 years. The number (N) versus magnitude (M) relations were then obtained for earthquakes originated in different regions in Japan.

3.23 T. Asada (359) discussed the mutual relations between the amplitude, acceleration, period and intensity and the frequencies of their appearences as obtained by different authors. He thus obtained possible relations between the amplitude and the predominant period from the above relations.

Noteworthy is the notice (31) pointed out by Asada and others on the conclusion drawn by Gutenberg and Richter that the energy released by small earthquakes is smaller than the amount released by large earthquakes. They proved that the above conclusion is nothing but the consequence of their definition of the class interval of the earthquakes, and that the same relation leads to the contrary conclusion that the energy emitted by small earthquakes is larger than the amount released by large earthquakes provided equal intervals in energy are chosen for the class intervals of earthquakes. It is also to be noticed that Kawasumi's law of equipartition of energy is another statement of the same fact when the earthquakes are subdivided into amplitude classes.

3.24 On the other hand T. Utsu (250) examined the time variation of the energy and frequency of aftershocks that accompanied the Tango, Oga, Tottori and other major earthquakes, while A. Seki (228) determined the relation between the maximum threshold distance of recordability by the Wiechert seismograph at Matusiro and the maximum distance of perceptibility by unaided senses of an earthquake, and found that the earthquakes in the Kinki district are better registered at Matusiro than those in the Tohoku district while the earthquakes in the Kwanto district are the worst recordable of those in the three districts.

Homma and Seki (300) compared the area (A) of aftershock occurrence and the radius (R) of perceptibility of the main earthquake and obtained a linear relation between log A and R, although the relations are somewhat different for land and ocean earthquakes.

Hitherto I have mentioned the studies on the magnitudes of shallow earthquakes (258), but recently methods have been deduced for the determination of the magnitude of a deep-focus earthquake by T. Hirono (216) et al and H. Honda (134). The former transformed Kawasumi's formula to determine the magnitude from observations of amplitudes with some theoretical considerations and obtained a formula to determine the magnitude of deep-focus earthquakes while the latter used the direct method of energy calculation based on the observed amplitude of the P and S waves, taking the mechanism of earthquake occurrence into consideration.

3.3 Time, Space Distribution of Earthquakes.

Hayakawa and Homma (202) et al discussed the migration of active centres of earthquakes in this country, while T. Tomoda (320) took a statistics of distances (S) between epicentres of the earthquakes in the Kwanto district on a convention to transform the problem into a one-dimensional problem. It is shown that the frequency f (S) is proportional to Sn where n is a certain constant, and a model is proposed to explain the relation statistically.

3.4 Observation of Surface Waves.

T. Nagamune (169) read the surface waves from the seismograms as recorded in three years by the Galitzin and the long period seismographs at the Matusiro Seismological Observatory. The superiority of the latter instrument has been mentioned already in chapter II of this report. He obtained dispersion curves of the Love

and Rayleigh waves for different paths over the Eurasian continent, North-western Pacific and Central-Pacific Ocean areas. These curves were used to infer the crustal structures with the results shown in the following table.

	Southern Asia			NW Pacific			Central Pacific		
	Vs	ρ	H	Vs	ρ	H	Vs	ρ	H
1st layer	3.3	2.7	14 Km	3.9	3.0	7.2 Km	4.1	3.2	33 Km
2nd layer	3.9	3.0	12	4.1	3.2	28.8			
Subcrust	4.3	3.4		4.8	3.5		4.8	3.5	

T. Akima's study (87) of the surface waves as observed at many stations in Japan at the time of the Great Indian Earthquake of Aug. 15, 1950 requires special mention. Although the seismograms used by him were those obtained by Wiechert seismographs with too short periods (4—5 sec) to be able to record the long period surface waves clearly, Akima could modulate them into fine seismograms which show the surface waves clearly by means of a low-pass filter of his own design. Thus he obtained reliable dispersion curves and the orbits of particle motions which indicate clearly the arrivals of these waves. From these dispersion curves it was found that the crustal structure in the SW Japan is different from that in NE Japan as follows.

	SW Japan			NE Japan		
	Vs	ρ	H	Vs	ρ	H
1st layer	3.2 km/s	2.6	14 km	3.4 km/s	2.7	27 km
2nd layer	3.4	2.7	12			
Subcrust	4.2	3.35		4.2	3.35	

But as will be described in the next chapter, the crustal structure thus determined cannot necessarily indicate the actual structure since the dispersion curve is not a unique representation of crustal structure in view of observational accuracy.

In the autumn meeting of the Seismological Society Akima (358) also delivered an address on the observation of surface waves.

Homma et al studied theoretically and endeavored to find the Sezawa (M_2) waves and allied M_2 and M_3 phases in actual observations.

In this connection special mention should be made on the discovery of T phases by K. Wadati and W. Inouye (1) in the seismograms of earthquakes of oceanic origin as observed at coastal stations in Japan. They found two phases T_1 and T_2 which were explained by the theory of Ewing and others.

As the conclusion of his long series of studies on the coda of earthquakes, S. Omote (17) elucidated the motions with the constant periods of 16 and 20 sec as the proper oscillations of the crustal layers below the station, while the fact that the mean period of

the coda increase with the epicentral distance was explained by him as the effect of firmoviscosity.

3.5 Mechanism of Earthquake Occurrence.

Under this title geographical distribution of first impulsions of earthquakes has been studied in this country. But those studies performed in the present period were comparatively few, among which those of H. Takagi (201, 224, 225, 226, 237, 238, 249, 256, 257) and H. Honda and T. Masatsuka (137) are to be mentioned. The former examined the distributions of ana- and kataseisms of any earthquakes to prove his explosion hypothesis on the cause of earthquakes as will be described in the next chapter, while the latter also studied the same from another hypothesis that the earthquake is generated by faulting motion in the earth's crust.

The former states that the distribution of the first impulsions of almost all the earthquakes are explained by the mechanism of conical type in which the wave of initial compression is radiated from the hypocentre inside the cone surface while the wave of initial dilatation is radiated into the remaining space or vice versa. But the latter held the opinion that these two waves are devided by two perpendicular planes into quadrants. The reviewer, however, has had the opinion that both of the mechanisms exist in actual cases.

Any way the systematic geographic feature of presumed seismogenic forces are interesting.

3.6 Other Seismometrical Observations.

K. Kanai's observations (16, 98, 114) of earthquakes at various depths down to 450 m in the pit of the Hitati copper mine are of some interest. The variation of amplitude with depth and the angle of incidence was examined and compared with the actual crustal structure found by seismic prospecting (54). The wave forms of the P and S waves were then shown to conform with those calculated theoretically with the instrumental constants and a certain assumption on the mechanism of earthquake occurrence (71).

Reducing theoretically the observed amplitudes of initial motions to the values to be observed at the hypocentral distance of 100 km, he found that the reduced amplitude varies almost proportionally to the square root of the period. On a simple assumption on the mechanism of earthquake occurrence he deduced that the energy of an earthquake is proportional to the cube of the period. He also made comparative observations at a station situated on alluvial soil and at the Hitati mine which stands on granitic foundations. Although the distance of the two stations is only 6 km, the amplitudes at these places showed marked difference in the motion with a certain period.

Nagamune and Seki (171) compared also the seismograms obtained at Nagano and Matusiro, but they could not find any marked difference between them so long as the same type of instrument (Wiechert seismograph) is used, although the mutual distance of these stations was 13 km. It is to be noted that the seismogram at Matusiro is somewhat simpler than those at Nagano.

S. Hata (207) determined the amplitude factor of seismological

stations by which the observed amplitude at the station is magnified or minified above or below normal.

T. Minakami (39) observed the amplitudes of volcanic tremors at various points around the Mihara Volcano in the summer of 1950, and deduced the relation between the amplitude and the distance of the observing station from the crater. It is thus shown that the tremors are the surface waves diverging in two dimensions in the firmo-viscous medium whose coefficient of viscosity is $1\text{-}2.7\times10^{9}$ c.g.s.

On the other hand A. Kubodera (336, 380) elucidated the amplitudes of first impulsions of the North Idu earthquake by the relation

$$H = ce^{-k\triangle}\sin 2\,\varphi$$

where H is the amplitude of the first impulsion and $\triangle$ and φ are the epicentral distance and azimuth respectively. The attenuation coefficient k thus worked out were 7.9×10^{-7} cm^{-1}, 1.3×10^{-7} cm^{-1}, and 2.6×10^{-8} cm^{-1} for Pg, P* and P_n respectively. By means of a theory on visco-elasticity he propounded that the dispersion due to this property is sufficient to explain the increase of velocity from 5.5 km/s to 6.0 km/s by the variations of period from ca. 0.1 sec to 1 or 2 sec.

3.7 Studies on the Travel Time Curves.

Among the few studies on this problem, Yosiyama's discussion (308, 415) of the effect of the magnitude of the hypocentral region in the study of the travel times of the Fukui earthquake of June 28, 1948 deserves notice.

Kisimoto (321) used mean travel time curves for the study of 13°-20° discontinuity, Kosikawa's study on the travel times of the Imaichi earthquake has already been mentioned (424).

3.8 Explosion Seismology.

The results of the first explosion seismic observations in NE Japan of Oct. 1950 were reported to the Brussels conference (15, 306). Henceforward 6 of such observations have been executed up to the present in the same region by the same Explosion Seismic Study Group consisting of members of the Earthquake Research Institute, the Geophysical Institutes of the Tokyo, Tohoku, and Kyoto Universities, the Kyusyu and Akita Universities, the Central Meteorological Observatory, the Science Museum of Tokyo, the Geological Survey of Japan and the Latitude Observatory of Mizusawa (90, 121, 356, 361, 367, 437, 438, 439).

The synopses of them are shown in the following table. The last Kamaisi observation was made in May of this year, so that it is omitted in this table. The most conspicuous result of these observations is the fact that the so called granitic layer with P-wave velocity ranging between 5 and 5.5 km/sec is lacking in this district. The boundary of the first and the second layers with velocities of 5.8 km/sec and 6.2 km/sec respectively seems to incline about 5°-9° westward.

Table 2. *Explosion Seismic Observations.*

	Shot Point	*Date*	*Time*	*Explosives*	*Spread*	*No of Stations*	*No of Observers*	*△ max.*
	39°06'21"N							
1st Isibuti	140°51'37"E	'50.X.25	12 h. 06 m	Carlit 57 ton.	S	8	16	129 km
	223 m		07 s.					
	39°06'22"N				Vicinity	4	12	
2nd Isibuti	140°53'39"E	'51.II.27	12 h. 06 m.	Carlit 7,8	E	7	16	160
	300 m				S	7	19	
	39°06'21"N							
3rd Isibuti	140°53'39"E	'52.VII.25	12 h. 04 m.	Carlit	S	13	30	327
	300 m		59 s. 42	5.546	W	6	10	
	39°17'36"N							
1st Kamaisi	141°41'48"E	'52.II.7	03 h. 34 m.	Dynamite	S	13	30	510
	500 m		59 s. 91	29.7	W	6	14	
	40°19'00"N							
Hanaoka	140°32'07"E	'53.VI.9	14 h. 05 m.	Carlit 2	Vicinity	5	9	24
	100 m				E	2		
	39°17'41"N			Carlit of				
2nd Kamaisi	141°41'28"E	'53.IX.13	03 h. 04 m.	dyna-	S	4	36	332
	500 m		57 s. 07	mite 42	reflexion	1	3	

This crustal structure seems to be well reflected in the gravity anomaly as deduced recently by C. Tsuboi (5).

General reports of these studies will be contributed to the coming conference in Rome this year.

3.9 Model Seismology.

The agar-agar which is a special product in this country is much used in model experiments because of its feasibility of casting and its low elasticity. K. Kasahara (88, 101, 115) of the Earthquake Research Institute used it as a medium for model seismology, and obtained results of much interest.

In the experiment in his first report a line exciter gave a short impulse on the surface.

The waves thus generated were picked up through capacity changes between two parallel plates, the one placed on the surface of the medium and the other fixed in the air at a small distance. The time distance curves within 40 cm were obtained, which gave the velocities of P, S and Rayleigh waves. They were

$$V_p = 6.1 \text{ m/s}, \quad V_s = 2.4 \text{ m/s}, \quad V_r = 2.2 \text{ m/s},$$

and the materiel constants thus obtained were

$$E = 1.7 \times 10^5 \text{ c.g.s.} \quad \mu = 0.61 \times 10^5 \text{ c.g.s.} \quad \text{and} \quad \rho = 1.$$

The surface profile at an instant and the motion of a point on the surface were also observed. These were elucidated in the second report by theoretical calculations. In the third report waves generated by the exciter, embedded at a depth and forced to move along eliptic orbits of variable ellipticity and inclination, were examined.

The distance of first appearence of Rayleigh wave was also observed.

On the other hand, D. Simozuru (74) and S. Sakuma (89, 100. 122) of the same Institute measured the elastic constants of bodies under initial strains or high temperature. The former observed lateral vibrations of a cylinder under axial pressure, to determine Young's modulus, while the latter measured the statical bending of a bar of volcanic rocks in high temperatures up to 1100° C to obtain Young's moduli and coefficients of viscosity. A rapid decrease in the values of these constants was observed at 700°-800° C, although the Young's modulus of a lava from the volcano Mihara showed a slight augmentation at lower temperature.

3.10 Historical Seismology

Lastly M. Keimatsu's study (355, 369, 370) on Chinese historical earthquakes is to be mentioned. As an historian Keimatsu has collected exhaustively the records of earthquakes from authentic histories as well as local chronicles. He is now investigating these data geographically and historically. In the present period, a result of his study on the great earthquake of Hainan Island, China on July 13, 1605, was published. This earthquake has been considered erroneously as a small earthquake at Luchuan, Kuangtung Province, but it is revealed that this is a large one of magnitude $M = 7.7$ originating in the Chiungchou strait by this study.

Similar studies are being made on many other earthquakes by him and their publication is expected.

3.11 Microseisms.

The study of the microseisms was comparatively fruitful in the present period. Most conspicuous among them was the paper by K. Wadati and W. Inouye (413), which was presented to the Brussels conference. It contains comparative simultaneous observations of microseisms at 14 stations in Japan in cases of 5 typhoons and one cyclone. Hourly readings of periods and amplitudes of the three components of microseisms were compared with the distance of the centre of the low from the station and the roughness of the sea at near coasts. Although the microseisms are closely related to the approach of typhoons and cyclones and the accompanying roughness of the sea, considerable timelags amounting to a few hours are observed everywhere between these phenomena, which fact favours the hypothesis that the microseisms are generated somewhere near the coast by the swells of the sea rather than the hypothesis that they are generated at the centre of a typhoon. The relation found by P. Bernard that the periods of microseisms are half of those of swells is not always the case in Japan. Bernard's relation seems only to hold when the typhoon passes above a deep sea area. Regional characteristics of microseisms are also found.

F. Kishinouye and R. Ikegami (34, 35, 51, 62, 63) made tripartite observations of microseisms and the directions of propagation of them were examined in relation to the positions of the centres of typhoons and discontinuity lines. The results showed that the direction of approach of microseisms varies in short intervals by almost 180 degrees, although the main part of them comes from the side of the typhoon centre. Comparison of periods of microseisms and those of ocean swells is also made by them, but no definite fact in support of Bernard's relation was found.

Local microseisms were also studied by others at several stations (208, 210, 211, 218).

3.12 Well-known Mallet's method of determining an epicentre from the observation of the direction of overturning of objects in the meizo-seismic area was applied so frequently that statistical procedures to obtain a most probable position of the epicentre have also been worked out by several scholars. Least objectionable theoretical procedure was introduced recently by Y. Sato. It is based on the assumption that the sum of squares of the perpendicular distances from the epicentre to the line of overturning directions is minimum (77).

Chapter IV. *Theoretical Investigations Related to the Elastic Waves and Allied Problems.*

4.0 In Japan the field of theoretical seismology related to the elastic wave theory was opened by the eminent pionneers as H. Nakano and K. Sezawa. After their deaths it was succeeded to and has been cultivated by younger students. It has not only proved to be the most fruitful field but has also become the characteristic branch in Japanese seismology.

The problems dealt with in the present period cover the whole field of the elastic waves as well as the fundamental problems of the theory of elasticity and allied mathematics.

4.1 Mathematics. Y. Sato extended his study on the transformations of the wave functions due to the transformations of the reference axes, and obtained also elaborate formulas concerning the transformation of potential functions (111).

The transformation of spherical surface harmonies was also solved by T. Takahasi (427) by the aid of the theory of rotation groups and generalised spherical harmonics. Elegant as the proof may be, the latter's result is only of theoretical interest at present owing to the lack of numerical tables of the special functions involved therein.

T. Rikitake (91) proposed an alternative method to those of C. Tsuboi and T. Nagata of inferring the subterranean structures from the observed forces due to gravity or magnetism on the plane surface. He substituted the Hermite function for Fourier series used by the latter.

4.2 The finite strain theory of elasticity founded by F. D. Murnaghan was extended by Y. Shimazu (327, 360), and eight kinds of expressions for the exact stress-strain relations were elaborated. He also estimated the wave velocities in cases when various finite initial strains were given. A discussion of the apparent anisotropy due to some initial strain and of its polarisation effect which is specially remarkable in the S-wave were also included. Noteworthy also is his negative conclusion on the possibility of detecting velocity variations in the regions where deformations of the crust due to imminent large earthquakes are in progress.

4.3 S. Homma, who had been interested in the generation of elastic waves from a given initial displacement or velocity, elucidated

theoretically the waves in cases when either dilatation or rotation within a finite region was assigned initially, and worked out some numerical examples (162, 312).

H. Takagi's proposal of a special hypothesis on the generation of earthquakes by explosions taking place in magma reservoirs has already been mentioned. He also elaborated theoretical models giving rise to such distribution of first impulsions on the theory of elasticity. Many actual earthquakes were examined from this point of view, and no exception was found even though the effect of the crustal structure were taken into consideration. But the reviewer cannot pass without remarking that there is no cognate relation between his mathematical model and his explosion hypothesis.

K. Kanai (71) calculated theoretically the motion of generated waves due to a certain mechanism which was proved to be in good accord with the actual earthquakes as observed at the Hitati Mine.

4.4 Theories on the reflexion and refraction of plane waves at parallel interfaces of homogeneous media or at the surfaces of a medium bounded by 2 perpendicular planes, or in the heterogeneous media in which density or rigidity varies in the direction of the wave normal were treated by several authors. (119, 138, 139, 160, 204, 239, 335).

H. Honda et al (135) discussed the reflexion of ScS waves due to a deep earthquake and inferred that the core of the earth is in a liquid state. He also studied the generation of waves due to a simple vibratory origin in a semi-infinite liquid underlain by an elastic solid by the use of Weyl's integral.

4. 5. 1 The problems of surface waves are an inexhaustible source of studies of the theoretical seismologists. Papers dealing with these waves appear almost incessantly even in Japan, and important contributions are here found. The most eminent authors have been S. Homma and Y. Sato, but the former died a much lamented death in 1953. The late S. Homma (159) obtained the solution in two dimensional problems of the waves in dispersive media satisfying boundary conditions first in the form of definite integrals by means of the Fourier-Bessel expansions. And the integrals were evaluated by the method of a stationary phase. It is thus revealed that the maximum amplitude A_m varies according to the relation

$$A_m \backsim r^{-n}$$

where r is the distance from the origin and

$$n = \begin{cases} 5/6, & \text{when U is maximum or minimum, ,} \\ 3/4, & \text{when U is mini-max., and} \\ 1 & \text{in other ordinary cases,} \end{cases}$$

provided U stands for the group velocity.

He also investigated the waves propagated in a special infinite or semi-infinite medium in which the density or elasticity or both varies or very continuously in the direction perpendicular to the wave normals (160). He obtained solutions in these cases by means of the hypergeometric or confluent hypergeometric functions, and a few

special numerical examples were worked out, but general calculation seems nevertheless to be very difficult.

He (168) also obtained an approximate solution of the waves of the Love type when the thickness of the surface layer varies very gradually, but the conditions assumed in this theory are presumed to be almost impossible to be satisfied in actual earthquakes because of their long wave lengths.

4.5.2 The Sezawa (M_2) wave which was first suggested 15 years ago was recently identified in actual earthquakes. K. Kanai (11, 12) who collaborated in the study with K. Sezawa examined the conditions of existence of this wave, and found that, for some domains of the ratio of rigidities in the crust and substratum and wave length, there are no M_2 waves although the ordinary Rayleigh waves exist in all cases. The direction of motion of the earth particle caused by this wave was shown to be the reverse of those of the ordinary Rayleigh waves.

Kanai also examined the minimum group velocities of the Rayleigh, Sezawa and Love waves, and proved that of the first to be about 1/2 of those of the latter in ordinary cases while the period of the M_2 wave with the minimum group velocity is about 1/3 of those of the other waves.

4.5.3 The long series of papers up to the ninth paper on surface waves by Y. Satô has been published since 1951. This is one of the remarkable contributions of Japan to our science. Although the items treated by him are not confined to new and conspicuous problems, his indefatigable effort to establish step by step the theory of surface waves on firm foundations must be appreciated.

In his first paper (8) the velocity equation of the Love wave was interpreted from the geometrical optics and the minimum velocities of as many as 152 branches of Love waves were calculated.

Then in the second paper (26) the waves propagated in plates were discussed exhaustively and their physical meanings were shown clearly. The problems treated in the above two papers were also discussed independently by M. Ewing.

In the third paper (47) Love waves in the two-layered crust were discussed, and the necessary and sufficient conditions for their existence in this case were shown to be that the velocity of S wave in the subcrust is not the minimum among those in the three media. In the same paper the continuity of the group velocity in this case was proved and the conditions for the existence of an upper bound in the phase velocity were also determined.

In the eighth paper (102) Satô constructed a nomograph for the calculation of the phase velocity and the period of Love waves propagated along a one-layered crust. The nomograph is also to be used to determine the relations of the material constants when the dispersion curves are known previously.

In the ninth paper (118) is given a nomograph to determine the group velocity of the Love wave when its phase velocity is prescribed. The inaccuracy and the labour of calculation may thus be avoided. These must be a contribution to the Oceanology for the discussion of the waves propagated along the continental shelves.

In his fourth paper (56) the possibility of determining an equivalent single layer is discussed. It is proved that we can find an equivalent single-layered structure which gives an almost identical dispersion curve of the Love wave with that of a two-layered structure, but the material constants in the equivalent layer are much different from both or the mean of those in the actual two crustal layers, although the thickness is not so divergent. This current convention is thus proved to be useless in deducing the true crustal structure. This must be a great alarm to the geophysicist at large.

In the fifth paper (67) Love waves propagated in a two-layered crust when the rigidity in the subcrust increases linearly with depth are discussed rigorously, and an amplitude variation with depth and a dispersion curve are calculated rigorously. This may be the most profitable solution applicable to actual cases.

In the sixth paper (78) the generations of Love waves and SH-waves from a simple origin are treated. In this paper the reciprocal theorem between the motions at the origin and a point on the surface is first proved, and the integral representation of the displacement due to simple harmonic motion at the origin is then derived, and the solution for the refracted wave thereof is obtained and the predominance of the wave with a particular period is shown. Lastly the relation between the period and the amplitude of the Love wave is obtained for its various branches. This problem was discussed by Jeffreys and Sezawa more than a decade ago, but an advance in our knowledge is marked by this study.

In the seventh paper (92) travel time curves of Love waves were theoretically obtained. More than twenty years ago the travel time curve and the distance of first appearance of Rayleigh waves from a source at a depth were theoretically obtained by H. Nakano, but no such theory for Love waves had yet been obtained. Satô found that the Love wave is composed of two waves with obvious meaning from the theory of geometrical optics, and that each of the two have individual distances of first appearance and corresponding travel time so that the resultant Love waves have a finite intercept time which varies with the wave length.

Moreover Satô published two papers (9, 48) of interest on the source at a depth or on the surface that gives rise to no Rayleigh waves.

It is also to be stated that the generation of Rayleigh and other elastic waves from a source of P-type situated within the crust in a one-layered medium is also solved theoretically by Satô and numerical calculation is in progress (10).

In the general meeting of the Seismological Society held at Matsusiro in 1952, Satô delivered an address (357) on elastic surface waves, in which he summarized the previous theoretical studies and proposed a definition and a classification of the surface waves.

4.5.4. M. Ichikawa (219) calculated dispersion curves for the Rayleigh waves propagated in a one-layered crust covered by an ocean, and lastly S. T. Nakamura (130) studied the attenuation of bodily waves and Rayleigh waves propagated in a kind of visco

elastic body in which the motion obeys the fundamental equations, such as

$$\left(a + \frac{d}{dt}\right)\frac{du}{dt} = c^2 \frac{d^2u}{dx^2}$$

as proposed in his previous papers.

4.6 Other problems to be mentioned in this chapter are those of statics. The late Mr. S. Homma (203) calculated the potential energy stored in the semi-infinite solid when the surface deformation is similar to those observed in actual earthquakes. He (161, 205) also studied the thermo-elastic deformations and showed that the seasonal change in the inclination observed in the cave at Matusiro cannot be explained by this effect alone.

Y. Satô (82, 95) contributed a paper on the effective elastic constants of a body with spherical cavities or spherical embeddings of different material distributed uniformly statistically.

Nakamura's method (132) of inferring the internal pressure distribution from the surface deformation is similar to those of Tsuboi and Nagata in the theory of Gravity and Magnetism.

Chapter V. *Applied Seismology*

5.1 Engineering Seismology.

5.1.1 Building Code.

In this preeminent land of earthquakes it is natural that engineering seismology is regarded as of great importance so far as the mitigation of earthquake disasters are concerned. Although many efforts have been made for seventy years for finding means of earthquake prediction, we must still confess that we are in no position to announce our success in this field. But we are now confident of preventing earthquake disasters arising from the destruction of civil engineering works if only ample means are at our disposal. Owing however, to the post-war circumstances, the new problem presented itself of finding economic methods of earthquake-proof construction; and therefore the seismologists are called upon for the re-examination of the current methods and actual structures, based on wider scopes on the nature of earthquake motions and their risks at the very point of every structure, with the results that a national building code was promulgated in 1951, in which the design strength of buildings is designated according to the kind of building and the earthquake risks in addition to subsoil conditions. Kawasumi's study (50, 441), already mentioned on the distribution of earthquake risks throughout the country was adopted as the basis. The whole country is thus divided into three zones A, B and C in which the seismic force for design was assigned as 0.2, 0.15 and 0.1 of the gravity (g) respectively. It is also prescribed that a building must be made so strong as to resist this seismic force multiplied by a foundation factor, ranging from 0.5 to 1.5 according to the kind of building and the subsoil conditions in each building site.

5.1.2 Foundation Factor.

Seismologists are now engaged in determining this foundation

factor from the actual observation, if any, of seismic intensities in the case of severe earthquakes, or from seismometric observations of minor earthquakes at ambulatory stations. The relation of this factor to subsoil conditions, such as geology, boring, resistance, bearing powers, the velocities of elastic waves and the thicknesses of the soil layers near the surface etc. are also examined, while the nature of the foundation factor is being studied experimentally and theoretically. The members of the Earthquake Research Institute, the Architecture Research Institute, Ministry of Construction and the Disaster Prevention Research Institute, Kyoto University, are active in this work (22).

5.1.3 Resonance Phenomena.

Although we have not yet obtained definite relations between the foundation factor and the subsoil conditions, important facts have hitherto been obtained (24, 41, 99). Among them, the discovery of the resonance phenomena in the amplitudes of earthquake waves due to multiple reflection in a soft layer or above harder foundation is to be first mentioned. It is true that the amplitudes of the seismic waves become larger on softer ground, but the soft soil layer is not necessarily worse as the foundation for all kinds of buildings if they are provided with sufficient bearing power at their foundations. The resonance phenomena of a building to earthquake motion plays so important a role in the destruction, that the nearness of the proper period of the building and the so called predominant period in the subsoil, and the damping force imposed to the motion of the building are the principal factors of the building destruction. It is almost established that the predominant period depends on the thickness of the soft alluvial layer, and the wooden Japanese house is more liable to destruction the thicker the alluvial foundation, within the range of 25-50 m in thickness, may be.

5.1.4 Experimental and Theoretical Studies.

Based upon these working hypothesis many experiments and observations are being carried out. K. Kanai was very active in this field. He proved the importance of the damping force in the building vibrations from the study of the damage of the concrete and masonry buildings in relation to the thickness of the alluvial layer, and then he proceeded to examine the vibration of actual buildings to determine the modes, the proper periods and the damping (66,79). He also measured the ground vibration at the same time in the vicinity of the building to prove the energy diffusion through elastic waves (55). Results of examinations of threetier buildings have been reported by him. He also proved theoretically the resonance phenomena at the surface of soil layers in the amplitudes of S-waves as the result of multiple reflections (70, 98, 113, 120). The firmoviscosity of the soil layer was also considered in the above discussion.

He also executed seismic prospecting of the structures of soil layers at the town of Ikeda Hokkaido, where marked difference in the damage was revealed on the alluvial and diluvial foundations in the case of the Tokati-oki earthquake. On the results he explained the greater damage on the soft peaty alluvial layer theoretically (99).

5.1.5 Subsoil Conditions and Earthquake Damage.

In the « Data Book of National Resources », No. 6 (441-447, 429-434) published by the National Resource Investigation Committee are collected papers on the distributions of earthquake risks and the foundation studies in Tokyo, Yokohama, Nagoya, Kyoto and Osaka. The results of investigations by the teams of the Kyoto University were summarized by R. Tanabashi in the Bulietin of the Disaster Prevention Research Institute (149). S. Yamaguchi (364) remarked upon the importance of the viscosity of the soil layer as revealed from the attenuation of amplitudes of surface waves in the field test with regard to the earthquake damage, but the reviewer is rather doubtful concerning viscosity thus determined (See also [289]).

T. Watanabe (305, 406) observed the propagation of periodic waves along the surface to infer the subsoil structure by the method used by the « Deutsche Gesellschaft für Bodenforschung ». But the members of the Earthquake Research Institute repeated similar tests and found that the wave which interferes with the direct wave and gives rise to the maximum amplitude at some distance is not necessarily the wave propagated along the substratum.

F. Kishinouye (73, 42) and R. Ikegami (23) observed the waves generated by a falling mass and explosives and the so-called «Tagesunruhe» on soft ground in Tokyo.

5.1.6 Vibration of Buildings.

Vibration of buildings caused by earthquakes and artificial vibration generators are observed for the purpose of detecting structural defects and the period and damping of free vibrations (330). K. Kanai's observations (25, 116, 123) have been already mentioned, but his discovery of the fact that the resonance peak of a reinforced concrete building on a soft foundation was lower than that of an exactly similar building on harder ground is of special interest.

N. Nasu (44) observed the forced and free vibration of a water tank tower, while T. Hisada and K. Nakagawa observed the forced vibration of a masonry construction up to the margin of demolition, which was well explained by the rocking motion satisfying a non-linear differential equation.

5.2 Seismic Prospecting.

The seismic prospecting by means of apparata imported from U.S.A. was more active than ever, and its field of application has been widened from the exploration of oil fields to those of coal seams (392, 394, 398, 407), as well as to examinations of foundations for civil engineering works as already mentioned. But basic studies, especially in the design and improvements of instruments have yet been slow inevitably.

5.2.1 I will only describe here important items of theoretical interests. M. Hayakawa's paper (284) on the study of some problems on seismic prospecting is first mentioned. It is the summary of his long year's study and experience, and includes the theory and practice of seismic instruments and examination of waves observed thereof and practical methods of field works and reduction of the data obtained.

T. Kaneko's contribution (288) on the reflection method is next mentioned. He examined the optimum charge of explosives and the depth of shot. The latter proved to have no important effect, while the relative position of the spread to the shot point showed marked effect on the quality of reflection impulse. Systematic study was also made on the group setting.

Several other theoretical and practical studies were also published (286, 393, 395, 396, 400, 401, 402, 405, 408, 409, 410, 411, 412).

5.2.2. On the other hand K. Tazime contributed a series of fundamental studies on the instruments for seismic prospecting (155-158). He applied the theory of electric instruments to that of the electromagnetic seismographs, and introduced the motional impedance to solve the equations of motion by the methods of circuit analysis. Thus he examined various kinds of current seismographs and devised methods of calibration of these instruments without using vibration tables. The coupling between pick-ups and galvanometers and the effect of self-inductions are also examined. His discussion on the definition of sensitivity (365) of a seismic instrument is to be specially noticed.

Chapter VI. *Geophysical Investigations Related to Earthquakes.*

6.1 Crustal Deformation.

In Japan precise levelling, triangulations, astronomical determinations of positions and soundings are performed repeatedly with the purposes of not only providing the people with accurate maps and charts but also of offering data of crustal deformations closely related to the earthquake occurrence (275-279, 324). Precursing subsidence and upheaval of land have attracted special attention in view of finding means of earthquake prediction. Continuous tidal observations (282, 323, 345, 346, 353), tilt-and extensometer observations are in vogue in this country.

6.1.1 Some of the important papers related to these studies will be reviewed in the following. Hagiwara (49) et al endeavoured to detect secular changes in the readings of water-tube tiltmeters and quartz-tube extensometers being installed at the Misaki Observatory of the Earthquake Research Institute. Eliminating the effects of temperature variations on the instruments and that of tidal loading, they obtained secular changes in tilt and elastic strains tolerably agreeing with similar data geodetically deduced for larger area. This fact is considered by them to be the evidence of the reliability of these instruments.

With the assistance of K. Kasahara (60), Hagiwara also examined the secular change in the relation between the tidal loading and the corresponding strain as deduced from the records of extensometers. But they could not find any marked change in the relation examined. This is an unharmonious fact to the inference of E. Nishimura that the elastic constants of the crust change markedly in accordance with seismic activity.

6.1.2 Noteworthy are the elaborate investigations on the crustal deformations throughout Japan by N. Miyabe (80). Based on the data for definite period as deduced from repeated precise levellings in

different epochs and continuous mareographic observations, he obtained the change of levels throughout the area with net adjustments. The results show conspicuous and reliable features of the crustal deformations closely related to the seismic activities in this country.

6.1.3 It is well-known that a remarkable crustal deformation accompanied the Nankai earthquake of Dec. 21, 1946. T. Nagata and A. Okada (109) repeated precise levellings 7 times after the earthquake in the vicinity of the Cape Murotozaki, in Sikoku, where the largest upheaval amounting to 1 m was experienced at the time of the great earthquake. It was revealed that the cape as a whole continues to recover i. e. to incline in the direction of S 10° E with diminishing velocity, the angle of tilt being expressed

$$\varphi = 4.50'' + 1.65''e^{-2.23t} - 0.035'' t$$

where t is the time in years since the great earthquake.

N. Nasu's levelling survey (30) in the Fukui plain after the earthquake of 1948 in the area revealed a fault to be presumed as the continuation of the Neo valley fault that accompanied the Mino-Owari earthquake of 1891.

Levelling surveys were also performed by F. Kishinouye (43), A. Okada and N. Nasu (125) in Tokyo and vicinity for the purpose of studying the subsidence of ground due to consolidation of the sedimental layers. This phenomenon was well studied by N. Miyabe (382).

6.2 Gravity

Two sets of each Worden and North American gravimeters were imported from U. S. A. and by means of which detailed gravity surveys throughout Japan have been performed.

6.2.1 The Earthquake Research Institute commenced in Feb. 1951 an extensive survey throughout Honsyû, Sikoku and Kyûsyû by means of a Worden gravimeter under the supervision of C. Tsuboi and has almost completed the work recently (2-7, 419). Nearly 4000 observations were made in the above area at every other one of the bench marks of precise levels. Similar survey was made by the Geographical Survey Institute in Hokkaidô; nearly 900 points were occupied. Contour maps of Bouguer anomalies based on the international gravity formula are published in our national report of the geodetic works prepared for the coming General Conference of the I. U. G. G. in Rome.

On the other hand Geological Survey of Japan and the Teikoku Oil Company have made detailed survey for exploration purposes, wherefore 33.000 observations have been performed (290, 294, 295, 296).

6.2.2 Repeated surveys were made in the Kwansai district by mean of the North American gravimeter through the co-operation of the members of the Geological Survey and the Kyoto University (315, 348, 349).

At the Volcano Mihara, Oosima Island, the Geological Survey repeated the measurements to find the change related to the volcanic activity (385, 287).

It is to be hoped that the crustal structures throughout Japan will be revealed by the analysis of these data and much light will consequently be thrown on the seismic activity in this country.

6.3 Special Studies on Earthquake Prediction.

6.3.1 Teams of seismologists of the Kyoto University under the guidance of K. Sassa and E. Nishimura (416, 418) are making special efforts to find clues for the prediction of earthquake occurrence. The latter compiled recently a summary of their observation systems and some encouraging results pertaining to these purposes (150-154). Their present interests are concentrated in the observations of crustal deformations (388) and the variations of force of gravity (301) and geomagnetic elements. Some of these observations are made at 15 stations throughout the country. Measurements of the variations of natural gammaray intensity and natural radioactivity of soil and rocks by means of Geiger counters and Lauritsen electroscopes respectively have been commenced with similar purposes (303, 341).

Having already obtained some useful facts, it is desirous to attain the final aim through persevering efforts of continuing uninterupted observations and painstaking works of eliminating the inevitable meteorological influences.

With similar and other purposes the crustal deformation is pursued through the reduction of tidal observations.

6.3.2. But I will here describe M. Hayakawa's study (285) of the time variation of the velocity of seismic P-wave in the region presumably subjected to preparatory strain for large earthquakes. He examined many earthquakes originated in the same region at different times to detect the time variation in the travel times, and obtained some systematic changes, but the time accuracy of these observations are not yet guaranteed to be sufficient (371).

6.4 Tsunami.

6.4.1 Just as we can obtain some clue on the coming danger of an earthquake from the statistical study of past seismic activity, so we can infer the menace of tsunami that accompanies a large earthquake of submarine origin. R. Takahasi (14) investigated minutely this problem. He took all the historical earthquakes accompanied by tsunamis, eighty-four in all, which took place under the sea along the Pacific coast of Japan. He estimated the magnitudes of tsunamis at their origins, and calculated the trajectories of the waves from these centres. From these he determined the energy, per unit length, arriving at a point on 200 m isobaths along the coast for each tsunami. The mean of this energy per unit length per century was taken by him as a factor of the menace of tsunamis. He then deduced the topography factor for the variation of square of amplitude as it proceeds from the 200 m isobath to the coast. Taking the product of these two factors, he obtained the expectancy of the energy of tsunamis per century per unit length at any place on the Pacific coast of Japan. This value is, in his opinion, nearly proportional to the area of inundation by a tsunami or in other words, the amount of damage, so that this is an important danger index of tsunami at each point.

6.4.2 Simozuru and Akima (85) found a peculiar phase in the mareograms of the tsunami as observed at various points in Japan in case of the Nankai Earthquake of 1946, and inferred it as the reflected wave from the submarine bank along the margin of the Phillippine Sea.

Mathematical theories on tsunamis were also investigated (29, 131, 133, 206, 217), among which those on sea waves caused by a progressing crustal deformation under the ocean and on the effect of circular island by S. Homma (206,217), and the same of submarine topography by T. Okano are to be mentioned. T. Rikitake's paper (29) on the reverse problem to obtain the form of tsunami at the mouth of a bay from the data inside the bay belongs also to this category. Hirono (167, 314) studied the method of drawing wave fronts of tsunamis on charts of various projections.

The actual field observations of tsunami that accompanied the Tokati-oki Earthquake are reported by many investigators (129, 140, 141, 142, 267). The records of tsunamis obtained in Japan in case of the Kamchatka earthquake of Nov. 5, 1952 (283, 423) were examined by the C. M. O. (248) and S. Yamaguti. (See also [251]).

6.5 Volcanic Phenomena.

6.5.0 Mt. Mihara, Osima Island continued from 1950 to 1951, the most conspicuous activity since 1778 ejecting volcanic bombs and lapilli and flowing out enormous amount of lava from its crater (166). The remarkable submarine eruption of the Myôzin-syô which wrecked the 5-th Kaiyô-maru with the lives of 9 scientists together with its 22 crew began in 1952 and continued till 1953 (244, 245, 246, 252, 351), while the Mt. Aso made a sudden eruption in 1953 and injured several visitors. But these phenomena of pure volcanology will here be left out of account (212).

6.5.1 Minakami's seismometric study of the volcanic tremors observed at Mt. Mihara and swarms of earthquakes which took place in the vicinities of volcanoes have already been described.

Seismic activity in Dec. 1943 that accompanied the birth of a new volcanic mountain in the vicinity of the Usu and the changes of surface and underground water in the surroundings were reported by K. Yanagiya et al (174, 175, 176) and T. Honda (186) respectively. T. Takeishi's report (227) on the volcanic tremors of Mt. Aso was also published (172, 173).

6.5.2 S. Sakuma's study (65) on the pressure of air-waves accompanied by the eruption of Mt. Asama on Sept. 23, 1950, based on the statistical data of the damage in window panes is very interesting. The damage was confined within a circle of 18 km in radius, but even in this circle interesting variation in pressure due to reflection and diffraction by the topography and large objects is clearly observed. At the marginary distance the pressure amplitude was estimated to be about $1\text{-}2\times10^{-2}$ atmospheres.

Part III. PHYSICS OF THE EARTH'S INTERIOR

In this chapter will be described the physical investigations concerning the earth's interior through observation of the crustal tide,

the gravity and the geomagnetism and theoretical inferences on the density, temperature, the properties and the motion of the materials in the earth's interior.

1 Crustal Tide.

1.1 Observation of crustal tide is now made by means of tiltmeters, extensometers and gravimeters. Tilt observation is classical in Japan, but a new problem arose from the discovery by E. Nishimura of a time variation in it, which may be ascribed to be the change of the rigidity of the earth's crust, but T. Hagiwara et al could find no supporting fact from careful observations at other points, of which I have already mentioned. From the observation of strain by means of extensometer, K. Sassa (147) and others could for the first time determine the Shida's number 1 specifying horizontal displacement at the surface due to any tidal strain of the second degree independently. It has hitherto been obtained in combination of the Love's number k from the analysis of latitude variation (328, 417) which cannot be free from considerable errors, so that the independent determination of 1 is very important. But recently I. Ozawa (148) showed from a detailed study, that the value of 1 thus determined is much influenced by the oceanic tide and others so that, to our regret, the method itself might be suspected in their usefulness. Other confirming investigations in this point at any mid-continental station are to be requested.

1.2 On the other hand H. Takeuchi (126) calculated theoretically the earth tide in the compressible earth of varying density and elasticity, based on the Bullen's model. The coincidence of the results with those observed is noteworthy. It is also shown that the rigidity within the core must be smaller than 10^{10} c.g.s.

2 Gravity.

The elaborate gravity surveys and the measurements in Japan to detect its changes in relation to seismic and volcanic activities have already been mentioned. Although the gravity method of underground prospecting (368, 372) is out of our present problem, the survey of national scale achieved will serve the elucidation of the crustal structures of the earth down to the depth of 100 km.

On the other hand Tsuboi's note (390, 391) on the possibility of deducing the vertical gradient of gravity from such survey is also of great significance from geophysical point of view. He revealed that the anomaly of the vertical gradient might be too large to be neglected in the free air reduction of gravity. N. Kumagai (421) discussed the error in the depth of isostatic compensation derived from the condition that the sum of squared residuals is minimum.

3. Geomagnetic Data.

With the exception of the seismic data of the velocity distribution of the P and S waves within the earth, the geomagnetism is a unique powerful weapon to infer the state at various depth in the earth's interior, although the depth attainable by this method is small compared with the seismic method.

With this in view, T. Rikitake analysed the variation of geo-

magnetic elements of comparatively long period, and studied the electromagnetic induction within the earth to reveal the electric state therein. Upon some assumptions he could deduce a discontinuity surface at a depth of about 400 km where the electric conductivity suddenly increases from ca 10^{-15} e.m.u. to 10^{-12} e.m.u. and continues to increase gradually up to the depth presumably of 1500 km (51, 68, 83).

Shorter period variations were also studied by him to infer shallower crustal structures (84, 96, 103, 104, 105).

4. Physical investigation of the earth's interior.

4.1 By means of the theory of ionic crystals T. Rikitake inferred the temperature distribution within the earth from the above mentioned distribution of the electrical conductivity, with the result that the temperature increases from ca. 1100° K at the lower boundary of the crust to ca. 3,000° K at the depth of 1,500 km. This is a new way of approach to the problem.

4.2 Y. Shimazu (307, 377) solved theoretically the density distribution within the earth with the assumption that (1) the material is in hydrostatical equilibrium, (2) the iron content increases linearly with depth within the mantle while (3) the core consists of uniform material. He used the compressibility as determined from the seismic velocities after Jeffreys and Bullen, and integrated differential equations numerically and the parameters and integration constants were determined so as to conform with the known values of the density 3.32 at the outer boundary of the mantle and the mean density and the moment of inertia of the earth as a whole. It was found that the Fe content of the mantle might be only 11 % in this model of the earth.

4.3 On the other hand, H. Miki (378, 379) examined the variation of the wave velocities in the crust and outer mantle on the assumptions of (1) constant increase of temperature, (2) the constancy of material composition and crystal structure (3) reasonable values of the Gruneisen parameter, and (4) the hydrostatic equilibrium. Characteristic discrepancies were found within the crust and at the depth of about 400 km. The former is ascribed by him to the failure of the hydrostatic equilibrium and the latter to the unusual variation of the Gruneisen parameter.

He (322, 329, 373, 387) also discussed the state inside the core boundary inferring the Gibbs' energy. Upon some inevitable assumptions he concluded that it is impossible to discriminate whether it is in liquid or solid state, and if the temperature is higher than a critical value to be prescribed by the atomic number Z (e.g.7000°K for Z less than 30) the material in the core will be in gas phase. A similar study was also contributed by T. Nishitake (302).

5. Dynamo Theory on the Origin of the Main Field of Geomagnetism.

To conclude the present chapter, the contribution of H. Takeuchi and Y. Shimazu on the origin of geomagnetic in field will be mentioned (376, 385). Elsasser's and Bullen's dynamo theories were taken up by these investigators and elaborate calculations were made to

solve the equations of motions of the material within the core of the rotating earth carrying electric charges. They could thus prove that stationary solutions exist which can fully explain the main field of geomagnetism. The motion consists of two kinds, the one being the rotation around an axis through the centre of the earth and the other a motion of convection type.

The necessary speed of the relative motion of the material in the core to the mantle was proved to be only 10^{-2} cm/sec.

The discussions of the mechanism of occurrence of these motions and the balance of energy etc. are to be expected.

Summarizing addresses of present status of the physics of the earth's interior were delivered by Y. Shimazu and H. Miki (274) at the Kanazawa meeting of the Seismological Society in May, 1953.

In conclusion the compiler wishes to express his cordial thanks to Mr. Y. Sato of the Earthquake Research Institute for his kind help. Many thanks are also due to the staffs of all the organizations and other investigators who offered him various data at his disposal.

APPENDIX A

PRESENT STATUS OF ORGANIZATIONS OF SEISMIC OBSERVATIONS IN JAPAN

Le Rapport National comprend une liste très complète des stations séismologiques en opération au Japon. Pour chaque station sont indiqués les coordonnées, les cosinus géocentriques : a, b, c et les constantes instrumentales. Faute de place, il ne nous a pas été possible de reproduire ici cette liste.

APPENDIX B

ARTICLES AND REPORTS ON SEISMOLOGY IN JAPAN DURING 1951-1953

* *THOSE PAPERS MARKED BY * ARE WRITTEN IN JAPANESE.*

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424.* KOSHIKAWA (Y.), On the Travel. Times of Seismic Waves. 1-8

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425.* SAWAMURA (T.), Crustal Movements by the Nankai Earthquake of 1946. 1-14

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433.* TANABASHI (R.), Relationship of the Nature of the Underground Formation Measured by the Elastic Wave and the Earthquake Damages. 23

434.* — The Underground Formation in Kyoto, Osaka and Kobe from the Standpoint of Earthquake Catastrophe. 26

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437.* The Research Group for the Explosion Seismology, Crustal Structure and Explosion Seismology.

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443.* KAWASUMI (H.), Distribution of Earthquake Damage in Tokyo and Osaka with Special Reference to the Subsoil Conditions. 18

444.* OMOTE (S.) and MIYAMURA (S.), Distribution of Earthquake Damage in Yokohama and Nagoya and Subsoil Conditions therein. 26

445.* TANABASHI (R.), Relation between Earthquake Damage and Subsoil Conditions as Revealed from Seismic Prospecting. 36

446.* — Subsoil Conditions in Kyoto, Osaka and Kobe as inferred from Earthquake Damage. 41

447.* — Risks from Earthquake Tsunamis and Prevention of Disasters caused by them. 43

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448.* SIRAI (T.), Foot Prints of Prof. Nagaoka. 146

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450.* MIKI (H.), An Evidence for Isostacy. 236

451.* Seizi Nakamura, Memories of Professor Aikitu Tanakadate. 376

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452.* SUDA (K.), Reflections on the Wreck of the Fifth Kaiyo-maru 124

453.* TSUBOI (C.), On the Wreck of the Fifth Kaiyo-maru, I. 248

454.* — On the Wreck of the Fifth Kaiyo-maru, II. 309

455.* TAKEUCHI (H.) and TAKANO (K.), Convection Current within the rotating Earth 605

MAROC

RAPPORT D'ACTIVITE

DU COMITE MAROCAIN DE GEODESIE ET DE GEOPHYSIQUE

(Section de Séismologie)

I. — *Observatoire - Appareillage :*

Le Service de Physique du Globe et de Météorologie de l'Institut Scientifique Chérifien dispose pour les études de Séismologie :

1° — D'un observatoire : l'Observatoire *Averroès,* situé près de Berrechid, à 60 km. de Casablanca et à 40 km. à vol d'oiseau du littoral.

Ses coordonnées sont :

Latitude 33° 18'
Longitude 7° 25'
Altitude 240 m.

Le sous-sol est constitué d'une épaisse couche (40 à 50 m) de marnes plio-pleistocènes.

L'appareillage comprend :

a) Deux séismographes horizontaux Maïnka (modèle S.O.M.) orientés NS et EW;

b) Un séismographe vertical électro-magnétique du type Wenner (modèle Coulomb-Grenet à moyenne période).

2° — D'une annexe à la station d'Océanographie physique d'Aïn Diab près Casablanca.

Cette station, qui fonctionne depuis 1951, est destinée à l'enregistrement des houles sur le littoral marocain. Nous avons profité de cette réalisation pour installer dans les mêmes locaux un séismographe vertical électro-magnétique spécialement destiné à l'étude de l'agitation microséismique.

Un relevé mensuel est adressé au Bureau Central Séismologique de Strasbourg ainsi que, par voie d'échange, à divers services séismologiques.

Des photocopies des enregistrements peuvent être communiquées aux observatoires sur leur demande.

II. — *Etudes macroséismiques :*

Des enquêtes macroséismiques détaillées continuent à être effectuées à l'occasion de chaque tremblement de terre ressenti au Maroc. Au cours des trois années écoulées, peu de séismes importants sont à signaler. Seul le tremblement de terre de profondeur exceptionnelle survenu le 29 mars 1954 dans le massif de la Sierra Nevada, au sud de l'Espagne, a eu d'importantes répercussions au Maroc où il a été ressenti jusqu'au 32° parallèle.

L'intensité a atteint par endroits, dans le Rif, l'intensité VII de l'échelle internationale. Une carte des isoséistes a été tracée; elle fait ressortir une répartition anormale des intensités. L'aire pleisto-

séiste est, en gros, limitée au domaine rifain (entendu au sens large), mais des îlots de perception isolés se rencontrent à plusieurs centaines de kilomètres de l'aire principale.

D'autre part, le Maroc oriental (à l'est du méridien de Guercif) n'a pas été ébranlé, tandis que des secousses sont de nouveau signalées en Oranie (à partir d'Oujda).

Cette répartition rappelle celle décrite antérieurement par *Wadati* pour les séismes profonds.

III. — *Travaux divers :*

1° — Les recherches sur l'origine de l'agitation microséismique et sur les relations de celles-ci avec la houle ou les mouvements de la mer sont poursuivies.

2° — Nous avons procédé à une révision complète des séismes marocains survenus au cours des vingt dernières années (1932-1952) et publié une carte des épicentres.

Ceux-ci se répartissent dans deux domaines principaux :

Domaine rifain (Rif et détroit Sud rifain).

Domaine atlasique (moyen Atlas et haut Atlas).

Le Maroc oriental apparaît comme tout à fait aséismique ainsi que l'anti-Atlas.

La meseta marocaine est peneséismique.

Ce travail fera l'objet d'une publication d'ensemble ultérieure accompagnée d'un essai d'interprétation géologique.

3° — Nous avons également, à l'occasion de cette révision des épicentres, pu étudier quelques raz de marée d'origine séismique, observés sur le littoral marocain.

J. DEBRACH.

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J. DEBRACH.

NOUVELLE ZÉLANDE

SEISMOLOGY IN NEW ZEALAND REGION : 1951-1953

1) *Seismological stations*

a) *List of New Zealand Stations; as at 31st December 1953.*

Station, Name & Symbol	*Position* Lat.	Long.	*Ht, above* M.S.L. (ft.)	*Lithologic* Foundation	*Equipment*
Wellington (WN) (Seismological Observatory)	41°17'S	174°46'E	401	Greywacke	Milne-Shaw (N-S). Galitzin-Wilip (Z). Wood-Anderson (N-S). Wenner (3 components). Imamura (3 components).
Auckland (AK)	36°52'S	174°48'E	250	Volcanic beds on tertiary sandstone & mudtsone	Milne-Shaw (N-S).
Karapiro (KP)	37°55'S	175°32'E	200	Greywacke	Wood-Anderson (N-S) x).
Arapuni (AP)	38° 5'S	175°39'E	212	Rhyolite tuffs	Milne (E-W) *).
Tuai (TU)	38°48'S	177° 9'E	960	Gravels	Wood-Anderson (N-S).
New Plymouth (NP)	39° 4'S	174° 4'E	112	Ash, agglomerate & lava	Wood-Anderson (E-W).
Tongariro (TO)	39°12'S	175°32'E	3,710	Volcanic ash and lava	Jones (Z) +)
Napier (NR)	39°30'S	176°55'E	10	Tertiary Limestone	Jaggar (N-S).
Bunnythorpe (BT)	40°17'S	175°36'E	197	Gravels, sands & silts	Imamura (3 components).
Cobb (CB)	41° 5'S	172°44'E	700	Schist	Wood-Anderson (E-W).
Kaimata (KM)	42°31'S	171°25'E	230	Moraine & river gravels	Wood-Anderson (NE-SW).
Christchurch (CH)	43°32'S	172°37'E	25	Alluvial sands, silts & gravels	Galitzin (3 components). Wood-Anderson (N-S).
Monowai (MN)	45°47'S	167°37'E	538	Tertiary sandstone	Jaggar (E-W).

x Established June 1951.

* Now used only for tilt measurements.

\+ Established October 1952.

b) *Stations outside New Zealand under the technical control of the Seismological Observatory, Wellington :*

Station	Position Lat.	Long.	Ht. above M.S.L. (ft.)	Lithologic Foundation	Equipment
Apia	13°48'S	171°46'E	7	Coral sand on volcanic rock	Wiechert 1000 kg. (H). Wiechert 80 kg. (Z). Wood-Anderson (N-S).
Suva	18° 9'S	178°27'E	20	Hard fine-grained calcareous marl	Milne-Shaw (N.-S.).

2) *New Zealand Earthquakes : 1951-52-53*

Tabulated list of earthquakes felt in New Zealand with instrumental magnitude (M) 5 and over; including all shocks with reported felt intensity M-M5 and over.

In the column «h» (focal depth), « S » denotes shallow focus, implying an origin within the crust, identified by the recording of associated pulses. « N » (normal) denotes an origin which may be shallow, but in which no crustal pulses were recorded.

Origin Time (G.M.T.) d. h. m.	*Provisional Epicentre* Lat. (deg.)	Long. (deg.)	h (km.)	M	Maximum Felt Intensity (M-M Scale)
1951					
Jan. 5 00 25	41.8 S	172.8 E	S	5 ¼	(4), Central regions.
10 19 15	42.8 S	173.2 E	S	5,6 ca	(7-8), widely felt in South Is., max. in Cheviot region.
10 19 23	42.8 S	173.2 E	S	5.1 ca	(«slight»), North Canterbury.
12 10 42	42.8 S	173.2 E	S	5,2 ca	(5), Central parts South Is.
13 06 41	42.8 S	173.2 E	S	5-5 ¼	(4), North Canterbury.
13 19 36	42:8 S	173.1 E	S	5.0	(6), North Canterbury.
17 16 57	42.8 S	173.2 E	S	5 ¼	(6-7), central parts South Is.
27 11 22	42.85 S	173.2 E	S	5.0	(5?), Canterbury.
Feb. 10 03 27	40.2 S	177.0 E	S	6¼-6½	(6), widely felt in North Is.
24 23 44	38.15 S	176.4 E	100	5 ¼	(4-5), north-east of North Is.
Mar. 23 21 39	31 S	180	300	7.6	(3-4), widely felt in North Is.
28 01 55	36.9 S	177.1 E	370	7 ca.	(4-5), widely felt in North Is.
Apr. 23 06 50	37.8 S	178.2 E	S	6 ¾	(7 ?), widely felt, max. in north-east of North Is.
May 29 04 01	40.9 S	172.6 E	S	5 ¼	(6), Central regions.
June 24 04 41	39.4 S	176.2 E	N	6 ¼	(6-7), widely felt, max. in central parts North Is.
25 18 33	38.6 S	175.9 E	S	5.1	(4-5), central parts North Is.
July 7 10 15	44.8 S	167.6 E	S	6.0	(4-5), southern part South Is.
Aug. 2 15 53	44 S	167 ¼ E	S	5.6 ca	(5), southern part South Is.
Sept. 4 23 23	38.9 S	175.5 E	150	5.4	(3) central parts North Is.
11 21 26	38.6 S	177.8 E	100-150	5¼-5½	(3) East Cape region.
30 13 40	38.7 S	178.6 E	S	5 ca.	(4) East Cape region.
Oct. 3 17 38	41.0 S	172.6 E	S	5.5	(5-6), widely felt.
6 10 44	40.2 S	174.8 E	N	4.2	(5-6), western parts North Is.
24 03 25	40.1 S	174.0 E	125	5.6	(4), widely felt.
Nov. 4 20 23	38.1 S	176.2 E	280	5 ½	(1?), Wellington region.
15 15 33	39.3 S	175.2 E	200	5.3	(2), northern part South Is.
Dec. 12 01 21	41.7 S	173.2 E	S	5-5 ¼	(4), north-west part South Is.
14 09 56	39.0 S	174.1 E	S	5 ¼	(4+), western parts North Is.

1952									
Jan.	1	06	12	39.8	S	177.0	E	S	5	(4), Hawkes Bay.
	9	11	03	39.8	S	176.6	E	S	5	(4-5), central parts North Is.
	12	16	30	38.7	S	176.1	E	S	5	(3), central parts North Is.
	18	04	47	39.8	S	176.7	E	S	5 ¼	(5), Hawkes Bay.
Feb.	10	05	56	38.6	S	177.8	E	100 ?	5.8 ca	(5) north-east of North Is.
Mar.	6	09	34	38.1	S	176.5	E	160	5 ¼	(4?) North Is.
	16	14	41	40.0	S	173.9	E	100	5 ca	(5-6), widely felt.
Apr.	9	14	08	40.7	S	177.3	E	S	5 ¼	(5), central parts North Is.
July	9	11	52	38.5	S	175.7	E	200ca	5 ¼	(2?), Wellington region.
Aug.	2	03	05	37.0	S	179.5	E	S ?	5 ¾	(2), North Is.
	28	10	40	39.9	S	176.9	E	S	5.8 ca	(6), central region.
	29	08	32	40.0	S	176.9	E	N	5.3 ca	(4), Hawkes Bay.
Sept.	14	21	14	41.2	S	174.1	E	S	5 ca	(4), Cook Strait region.
	17	16	17	40.5	S	178.2	E	N	5 ¼	(1), Wellington region.
	28	01	31	40.0	S	174.0	E	150ca	5.0 ca	(2), Wellington region.
Nov.	2	13	30	42.9	S	171.1	E	S	5.0 ca	(4-5), Westland.
Dec.	23	07	20	44.5	S	167.5	E	N	5.4 ca	(1), southern part South Is.
1953										
Jan.	12	07	08	39.25	S	177.55	E	S	4.9 ca	(4-5), Hawkes Bay.
	14	01	44	37.9	S	176.8	E	S	5 ½	(5), north-east of North Is.
Mar.	17	11	12	39.5	S	179.3	E	S	5.6	(2), north-east of North Is.
Apr.	2	20	22	42.5	S	173.4	S	S	5.1 ca	(4), central region.
	6	18	24	40.5	S	176.9	E	S	3.9 ca	(5), Hawkes Bay.
	11	10	29	40.4	S	174.7	E	60ca	5 ½ ca	(5-6), widely felt.
	18	16	49	39.1	S	175.6	E	S	< 2 ½	(5), central parts North Is.; volcanic shock.
May	11	09	14	39.6	S	174.1	E	190ca	5.3 ca	(3), southern part North Is.
	26	01	18	37.6	S	176.6	E	320ca	5 ¾	(1?), Wellington region.
June	8	20	36	40.25	S	173.65	E	160	6.0 ca	(3), central regions.
July	4	02	07	38.8	S	175.7	E	S	5.3	(6-7), central parts North Is.
Sept.	29	01	38	37 ½	S	176 ½	E	300ca	7-7 ¼	(7), very widely felt, max. in north-east of North Is.
Oct.	18	03	39	38½	S	174	E	N	5	(5) western parts North Is.
	28	12	22	40	S	177 ½	E	N	5 ½	(5) Hawkes Bay.

3) *Research*

During the years 1951-52-53, research work has been carried out on the following projects :

(i) The seismic geography of the Tonga-Kermadec region and its relation to the New Zealand region.

(ii) Analysis of the Aftershock Sequences of some New Zealand Earthquakes.

(iii) Direction of initial motion in local earthquakes, for correlation with Geological Survey field investigations on fault movements.

(iv) Analysis of the records of eruption explosions of Mt. Ngauruhoe, made by the seismograph at Chateau Tongariro.

(v) Seismic explosions for crustal structure investigations, carried out in 1951 and 1952, in co-operation with the Geophysical Survey and other Branches of the Geophysics Division. Reading and Analysis of records.

(vi) Measurement and study of ground vibrations due to microseisms and artificial disturbances in various localities, including the sites of existing and proposed seismograph installations.

Most of the projects listed above have not yet been completed and published. They have been the subject of papers and discussions at the Department's annual Geophysical Conferences.

Research work is also being carried out by Dr. C. B. Officer of the Woods Hole Oceanographic Institution, who came to New Zealand on the Fulbright Scheme in September 1953.

In the field of Engineering Seismology some further earthquake records from the Wenner Accelerometer have been analysed at the Dominion Physical Laboratory. Policy in this subject is guided by the Laboratory's Advisory Committee on Engineering Seismology, which includes a representative from the Seismological Observatory.

Publications

I. Routine Seismic Bulletins :

a) Monthly Provisional Bulletins, giving data for important distant and local earthquakes : bulletins P-223 to P-254 (1950 Sept. to 1953 April).

b) Quarterly Reports, giving detailed readings of all distant earthquakes and local earthquakes of magnitude 5 or more : bulletins E-116 to E-122 (1949 Apr. to 1950 Dec.).

II. Special Bulletins on seismology and related subjects :

a) HAYES (R.C.), Earthquakes in New Zealand during the Year 1948. *Seis. Obsy. Bull.*, N° S-91.

b) — Earthquakes in New Zealand during the Year 1949. *Seis. Obsy. Bull.*, N° S-92.

c) — The Cook Strait Earthquakes : 1950 Jan.-Feb. *Seis. Obsy, Bull.*, N° S-93.

d) GARRICK (R. A.), Observations of ScS near an Earthquake Epicentre. *Seis. Obsy. Bull.*, N° S-94.

e) HAYES (R. C.), Wave Periods in New Zealand Local Earthquakes. *Seis. Obsy. Bull.*, N° S-95.

f) — Earthquake Origins in New Zealand during the Year 1950. *Seis. Obsy. Bull.*, N° S-96.

g) — Earthquake Origins in New Zealand during the Year 1951. *Seis. Obsy. Bull.*, N° S-97.

h) DIBBLE (R.R.), The Testing and Selecting of Sites for Wood-Anderson Seismographs. *Geophysics Division*, Report No. 6.

R. C. HAYES,

Director, Seismological Observatory Wellington.

PAKISTAN

NATIONAL REPORT ON SEISMOLOGY

1. *History.*

On the request of the Government of Pakistan, a group of four Geophysicists under the leadership of Dr. G. Norgaard was sent by UNESCO to assist with the development of geophysical programmes initiated by the Meteorological Service and the Survey of Pakistan. The group arrived in Karachi early in 1951. H.I.S. Thirlaway arrived from the University of Sydney to take up the Seismological post in June 1951.

Because it is situated in one of more seismic areas of Pakistan, Quetta was selected to be the headquarters for seismological work. Training of Meteorological Service staff, and the installation of two Milne Shaw seismographs began there in the summer of 1951. Accurately timed records were first written on 27 Dec., 1951 in a store room of the Chiltan Hotel, and satisfactory recording continued there until September 1952. The first bulletin of the station was published in May 1952.

The arrival of a three component short period Sprengnether seismograph from UNESCO made it essential to find more space. A war time air raid aid station was offered by the military authorities. The Sprengnether equipment was installed in this building, and the two Milne Shaws transferred from the hotel store room. Suitable laboratory and office space was fortunately available in a building next to the instrument rooms.

Instrument piers were built directly on the concrete floor to a height of less than 12 inches. No part of the building was below ground. The Sprengnether periods were about 1½ secs. and that of the Milne Shaws 10 secs. No difficulties with tilt or drift were experienced.

Recording in this building began in September 1952, and continued until May 1954, when the instruments were removed to the permanent buildings about 6 miles West of Quetta. The new site was acquired at the end of 1951 when the buildings were designed. Construction began in September 1952, and work was completed during the spring of 1954.

Apart from the seismological instrument vault, laboratory, and offices, the new buildings house a geomagnetic observatory, laboratory, and offices; atmospheric physics laboratory, and offices; workshop, and drawing office. A new block for Hydro and Agricultural Meteorology Laboratories will be completed this year. About 200 trees have been planted in the observatory grounds in preparation for this work.

By this time, the main equipment, ordered by the Meteorological Service, had arrived, and Quetta is now carrying out routine recording with five component Sprengnether, three component Wilmore, and one component Milne Shaw seismographs. A visible recorder operated by a photo electric amplifier is also being used.

Two Milne Shaws were installed at Lahore during the summer of 1952. The temporary building there has not proved so satisfactory as those in Quetta, however, and many records have been lost through tilting. The permanent vault has been designed and construction will start this year.

On the request of the Central Engineering Authority, experimental work with a Milne Shaw began at the site of Warsak Dam, near Peshawar in March 1953 — This work has now been temporarily discontinued.

In April 1954 a three component short period Sprengnether station was established at Patenga near Chittagong. The first instrument of an experimental tripartite station was also installed together with a Sprengnether microseism recorder. At the time of writing training of personnel at this station is in progress. The full tripartite and earthquake instruments will come into operation during the summer of 1954.

2. *Quetta Observatory.*

Quetta is the headquarters of a network of short period seismological stations to be established at Quetta, Hyderabad, Lahore, Drosh (Chitral State) and Chittagong. Quetta and Chittagong are already in operation. Long period instruments are in operation at Quetta, and Lahore, and will also be installed at Chittagong. A Microseismic station is operating at Chittagong and Milne Shaws for this purpose will be installed at Karachi. Wenner Accelerometers are to be installed at Quetta, Warsak Dam, Dacca and either Sylhet or Pasni (Mekran Coast). Finally three sets of 3 component Wilmore instruments will be available for field work and special projects. A summary of the existing and proposed network is given in section 5. of this report. Most of the equipment for the full programme has been received.

To date Quetta is the only observatory which has been completed. It is sited at the northern end of the Chiltan Range, about 6 miles west of the city. The instrument vault is completely underground with a 5 ft. covering of grassed earth. The instrument piers rest at 15 ft. below floor level on a semi-consolidated conglomerate consisting of limestone boulders up to 2 ft. in diameter. Bed rock (Tertiary limestone) is estimated to be 10 ft. below the pier footings. The piers are constructed of 9 inch cubes of a massive Jurassic limestone set in cement mortar. The 30' $\times$ 22' floor space is divided into instrument and recording rooms by glassed partitions so designed that the full layout may be viewed without disturbing the equipment. Ample pier space exists for other equipment which may be required from time to time.

Steps from the vault lead past the photographic dark room into the main laboratory. The interpretation and map room is next to this laboratory. Two small offices, a small office — laboratory containing a 3 ft. square pier, and a battery charging room lead off from these two rooms.

3. *Seismicity of Pakistan.*

Baluchistan and the Baluchistan States Union is the most seismic area in Pakistan. Of this area, that within a radius of 200 kms. round Quetta is more active than the remainder.

Fold mountain ranges rising to a maximum height of about 3,500 metres cover the whole area. To the east the ranges fall steeply, possibly as a faulted monocline, to the Indus basin, while to the west they continue into Afghanistan and Persia. Rocks from the Trias to Siwalik series are exposed, and a small patch of Carboniferous has recently been discovered by the Geological Survey. North and south of the Quetta area the strike varies from south to southwest. Quetta is situated at the apex of a great re-entrant caused by the strike swinging from south through west to northwest, and finally back to south. Most of the earthquakes originating in Pakistan are associated with this great deformation.

Epicentres in this area closely follow the strike of the geological structures and accurate location of the active faults, using temporary field stations of Wilmore equipment, forms an important feature of the Observatory's work. One such fault striking southwest from Quetta has been located. Several earthquakes felt in Quetta during the last three years have originated along this fault. Periodical swarms of small shocks also occur along this feature. The epicentre of the Quetta earthquake of 1935 is on the line of this still active fault system.

Four other especially seismic areas are close enough to Pakistan to make them worthy of special study by our Observatories. These are Assam, Hindu Kush, and the edge of the continental shelf off the Mekran Coast. Earthquakes in these areas are commonly felt in East Bengal, Frontier Province and Mekran respectively. Those in the Hindu Kush usually occur at a depth of 200 kms. The submarine earthquakes are liable to generate seismic sea waves. The last one, in Nov., 1945, swamped large stretches of coast line including the port of Pasni, and reached Karachi at low tide with a height of 4½ feet.

During the past two years 34 earthquakes were felt in Pakistan. Of these, 12 were felt in the Quetta area, and 16 in northwest and northern Pakistan.

In all 237 earthquakes within a radius of 1000 kms. were recorded at Quetta between January 1952 to January 1954.

The largest of these earthquakes was that of Mekhtar, Baluchistan (10 October 1952) with a magnitude of 6½. This earthquake was followed by numerous aftershocks of small magnitude.

4. *Research.*

Activities outside the routine operation and maintenance of the Observatory have been confined largely to the task of collecting and analysing the data required to establish rational and economical earthquake building codes for Pakistan. Earthquake epicentres taken from I.S.S. since 1913 to 1943 have been plotted on the scale of $1:10^6$. Where known, magnitudes are assigned and converted to approximate maximum accelerations at the epicentres. Now that recording has

begun in Pakistan much greater detail is possible and lines of epicentres, which presumably reflect fault lines, are showing up clearly. Magnitudes based on Quetta's seismograms are estimated, and the approximate accelerations at the epicentres also computed as with the I.S.S. lists.

Provisional iso-acceleration lines are then drawn. These show the approximate maximum accelerations experienced in various parts of Pakistan over the past 50 years. As more data accumulates from Pakistan's network of observatories it is thought that this map will guide the design and re-inforcing of constructional works from the point of view of seismic risk with some detail. It is certainly an improvement on existing maps in which Pakistan as a whole is placed in the same class as the Assam - Himalayan - Hindu Kush area.

Eventually a map showing active faults, epicentres, and maximum accelerations will be published to assist constructional engineers and perhaps form the basis of official building codes.

Determination of detailed structures in the vicinity of active faults has also been undertaken using the Pye 4-Channel seismic refraction equipment. The problem usually consists of determining the nature of bedrock below a few hundred feet of gravels or alluvium. In the Baluchistan area, this has proved to be indirectly of value in the development of water resources.

A good record of the Chilean earthquake of 6 May 1953 enabled the identification of an apparent phase PKJKP. The details were communicated to Professor Bullen who is collecting the data on this possible phase.

Our experience with temporary observatories suggests that seismographs of less than 10 secs. period can be very satisfactorily operated on a concrete floor base in an ordinary surface building. Foundation rock types and ages affects short period equipment to a much greater extent than temperature and tilt, but even in Chittagong, where the equipment is installed in a small domestic house sited on stiff Quaternary clays at the mouth of the Karnafuli river, satisfactory records are being written at reduced magnification. This experience may encourage private institutions like Universities to operate short period equipment, especially in the seismic areas where a large increase in the number of observations would be immensely valuable.

5. *Station Data.*

a) *Established Observatories.*

Quetta

The Co-ordinates of the temporary site were : N. 30°12'.5, E. 67°02'.1.

Those of the new site are : N. 30°11'.3, E. 66°57'.0.

The height of the temporary site was 1710 metres and that of the new site is 1730 metres.

The constants of the Sprengnether equipment are as follows :

NEZ T (Pendulums and galvanometers) = 1.9 secs.
Damping critical.
Static magnification about 5, 000.
Paper speed 60 mm/min.

NE T (Pendulum and galvanometers) = 20 secs.
Damping critical.
Static magnification about 20, 000.
Paper speed 60 mm/min.

The constants of the Wilmore equipment are as follows :

EZ T (Pendulum) = 1 sec.

E T (Galvanometer) = $\frac{1}{4}$ sec.

Z T (») = 1/25 sec.
Damping critical.
Static magnification about 20, 000 for E.
Paper speed 53 mm/min.

The Milne Shaw constants are :

E T = 12 secs.
Damping critical.
Static magnification = 350.
Paper speed 16 mm/min.

The Sprengnether visible recorder is operated at present by a 1 sec. period Wilmore seismometer and a $1\frac{1}{2}$ sec. period Galvanometer.

Two clocks are in use, a self winding pendulum clock with usual escapement, and a Synchronome free pendulum clock.

Chittagong

The station Co-ordinates are N. 22°13', E. 91°47'. It is only a few feet above sea level, and the foundation is stiff Quaternary clays.

Instrument constants for the Sprengnether equipment are :

NEZ T (Pendulums & galvanometers) = 1.8 secs.
Damping critical.
Static magnification about 1, 000.
Paper speed 60 mm/min.

Tripartite instruments are operating at a period of 6 secs. with a static magnification of about 10, 000. The maximum paper speed is 360 mm/min. For initial experimental work, the three instruments are sited in temporary huts at the corners of a triangle with 1200 ft. sides.

Two normal pendulum clocks are in use, one of which gives time marks every 15 secs.

Lahore

The co-ordinates of the station are : N. 31°32'.6, E. 74°19'.7.

The single Milne Shaw component has a period of 10 secs., and a magnification of 250. The damping is critical, and drum speed

is 16 mm/min. Time control is by means of a U.S. Army Signal Corps Contactor Unit.

b) *Planned Observatories.*

Short period Sprengnether instruments having periods of about 1½ secs. have been received for use at Hyderabad, Lahore, and Drosh. Pendulum clocks will provide the time control at these stations. It is hoped to have this equipment in operation by the end of 1955.

Four sets of 3 component Wilmore equipment have also been received. One set will be used at Chittagong, and one at Warsak Dam site and other large constructional projects as found necessary. The other two will be used initially for detailed studies of the active fault zones in the Quetta area.

Accelerometers will be operated at Quetta, Warsak, Dacca and Sylhet or Pasni.

6. *Publications.*

Apart from the monthly bulletin of earthquake data, the Seismological Division of this Service contributes to the Technical Progress Review of the Geophysical Centre. This review is published twice a year, and summarizes the results and development of Geophysics in this country. Four numbers have already been distributed to observatories and institutions throughout the world. Copies of the Seismological Bulletin and the Review will be sent on application to the Director of Meteorological Service, Karachi.

It is hoped that a vehicle for the publication of occasional papers will be available during the course of this year.

S. N. NAQVI,
Director of Meteorological Service.

PEROU

NATIONAL REPORT FROM PERU

Seismological stations were operated in *Huancayo* and *Lima* during the past three years. The former is located at 12°02.7' S. Lat., and 75° 20.4' W. Long.; the latter at 12° 04.8' S. Lat., and 77° 03.5' W. Long. Two horizontal Wenner seismographs and one Benioff vertical component functioned in Huancayo and rather ancient Wiechert and Milne equipment in Lima.

A new vertical component Benioff was purchased for Huancayo, with both short and long period galvanometers and recorders; likewise new recording equipment for the Wenners. This equipment is now being installed. A visual recorder was also installed enabling

more active participation in the Seismic Sea Wave Warning System of the United States Coast and Geodetic Survey. A Montana type accelerograph belonging to the USC&GS operated in Lima under control of the Instituto Geologico del Peru.

Carrying out the 1951 Brussels resolution of the IAS a seismological station was built in Iquitos. A new Benioff vertical component seismograph is being installed.

Five slightly destructive earthquakes occurred during 1951; three in 1952 and one in 1953. A total of 298 shocks were actually felt in Peru during this three year period. Bulletin No. 8 of the Instituto Nacional de Investigacion y Fomento Mineros (INIFM) includes a macroseismic study of the destructive Cuzco earthquake of May 21, 1950. A Seismological Map of Peru is being prepared showing geographical distribution of seismic activity.

The Huancayo Geophysical Institute has published Bulletins 1 to 24 of Series S-A with seismogram data for 1950 and 1951; likewise those of Series SM-A, Nos. 1 to 27 covering 1952, 1953 and the first quarter of 1954, including also meteorological data. and, beginning with No. 6, microseismic data. The INIFM has published Bulletins No. 4 and 8 with Seismological Data for 1950 and 1951; 1952 is ready for the press.

The Huancayo Geophysical Institute extends a cordial invitation to all members of the Association who wish to investigate the many problems of its domain and offers all of the facilities at its disposal.

A. A. GIESECKE,
Director Tecnico
Instituto Geofisico de Huancayo.

PHILIPPINES

PHILIPPINE NATIONAL REPORT ON SEISMOLOGY

This National Report is a compilation of excerpts from technical papers and other publications published by the Philippine Weather Bureau which is the official government agency designated to take charge of seismological activities.

I. *Seismological observatories in the Philippines*

In connection with its seismic functions, the Weather Bureau maintains a central geophysical station located in Quezon City and five subsidiary stations; two of which are located in Luzon, one in the Visayas and two in Mindanao. The names of these stations, their geographic positions and the instruments used are given below :

Station	*Location*	*Instruments used*	*Remarks*
Diliman Geophysical Station	14° 40' N. 121° 05' E.	2 Sprengnether Horizontal Seismometers Series H (for Microseismic work)	Magnification - 5000 Oriented N-S and E-W
(Quezon City)	Elevation 70.4 m.	2 Sprengnether Horizontal Seismometers Series D - H	Magnification - about 3000 Oriented N-S and E-W
		1 Sprengnether Vertical Seismometer Series D - H	Oriented N-S
		1 Torsion Seismometer	Recording E-W component
Ambulong Geodynamic Station	14° 05' N. 121° 03' E.	1 Wiechert Inverted Pendulum Seismograph	Magnification - 200 Recording two components
(Ambulong, Tanauan, Batangas)	Elevation 10.5 m.		
Iloilo Station	10° 42' N. 122° 34' E.	1 Horizontal Seismograph (Local made)	Magnification - 14
(Iloilo City, Iloilo)			
Mambajao Station	9° 15' N. 124° 43' E.	1 Louckes-Omori Horizontal Seismograph	Magnification - 200 Recording two components
Davao Station	7° 04' N. 125° 36' E.	1 Strong Motion Horizontal Seismograph	Magnification - 2
(Davao City, Davao)	Elevation 19.2 m.		
Baguio Station	16° 24' N. 120° 34' E.	1 Strong Motion Horizontal Seismograph	Magnification - 2
(Baguio City)	Elevation 1507 m.		Incorporated with the Geophysical Station at Mirador, Baguio, owned and operated by the Society of Jesuits under Fr. Deppermann.

II. *Macroseismic Tremors*

In addition to the macroseismic observations reported from the above seismological stations, other reports are received from various sources most of which come from cooperative seismic observers. Many of these observers are also the meteorological observers of the Weather Bureau, who are assigned in provincial stations. In order that a more even distribution of seismic observers may be effected, the Philippine Weather Bureau made arrangements with the Bureau of Public Schools late in 1953 to have some of its teachers deputized as seismic observers. As of today, a total of seventy-eight (78) elementary science teachers assigned in various strategic places in the Philippines have been appointed cooperative seismic observers in addition to the original number maintained by the Bureau. They have been provided with instructions and report forms.

Where sufficient macroseismic information is received concerning an earthquake, isoseismals are drawn, the directions of motion in

the different localities are plotted and the character, duration, accompanying phenomena, etc. of each reporting station are noted. These observations help, to a great extent, in the determination of the epicenters, study of the behavior of the earth's crust in the different parts of the archipelago and in the determination of the fault regions. These fault regions, in so far as they have been determined, are based on seismic, geologic and hydrographic evidences and have been inferred from the distribution of some hundred odd epicenters of earthquakes that had visited the Islands in the last four hundred years. They were enumerated and described by Mr. Arturo Alcaraz, former Geophysicist of the Weather Bureau in his paper « The Major Structural Lines of the Philippines ».

III. *The Diliman Research Project*

During the war years when communication facilities were disrupted by war operations, the need of forecasting the weather by means which were independent of meteorological observations from widely scattered sources had been felt. The U. S. Navy, realizing the necessity of accurate weather forecasts in its operations, initiated a research on microseisms with its Microseismic Research Project in the Caribbean, which was extended to the Pacific in 1945. In 1949 the Philippine Weather Bureau started a research project of its own, established a tripartite microseismic station in Diliman, Quezon City and carried on daily exchanges of data with the U. S. Navy at Guam. With three very sensitive seismometers of the electro-magnetic type complete with photographic records at its disposal for the detection of microseisms, the Diliman Station was well equipped to carry on its research project.

In the investigations of the Diliman Station on the relationship between storms and microseisms the following procedure was observed. First, the meteorological characteristics of a storm such as the wind velocities near the center, the position relative to the recording station, i. e., its distance and bearing, the depth of the water beneath the storm center, etc. were first gathered. Then the microseisms accompanying the storm were compiled and an intensive study was made to determine what relationship existed between storms and microseisms. Using this method, all meteorological disturbances in 1951-1952, from typhoon IRIS to typhoon BABS (16 cases) were investigated.

The results of the investigation showed that the amplitudes increase as a storm approaches the station or when the storm intensifies and that there is a decrease in amplitude on passage of a storm from deep to shallow water or over land. The effects on microseisms due to the presence of the Philippine Deep, located just off the eastern coast of Mindanao was also studied. There was a possibility that this Deep, regarded by many geologists as a fault zone, may act as a microseismic barrier causing the damping of microseismic waves. Two years of investigations, however, have produced findings which seem to show that the microseisms do not show any decrease in amplitude in the case of a storm separated from Manila by the Deep and in fact even showed an increase when a storm intensifies in that general area. The observational results so far obtained

appear to fit best the theory which assumes that the energy from a tropical storm is transmitted by some coupling mechanism directly to the ocean floor to generate microseisms. Other results obtained aside from the above must wait for further observational data before regarding them with certainty as natural laws.

The Tripartite Method. — Late in 1949 the tripartite method of determining bearings of typhoon was tried at the Diliman Station. At the start the instruments were oriented with the free ends due north until December 10, 1949 when they were reoriented to the northeast. In August of the following year they were returned to their original positions.

Observations of amplitude and period were made at 0000 Z and 1200 Z and, during a microseismic activity, at 0600 Z and 1800 Z. The amplitudes reported were the averages of the ten largest double amplitudes (trough to crest) recorded in the hour preceding the synoptic hour, while the period was the average of ten regularly formed waves chosen at random.

While computed bearings as determined by this method were close at times to the true bearings of the storms, and in some cases even pointed directly to the storm centers, there still leaves much to be desired. For one thing they lacked consistency and the margin or error was above what might be considered satisfactory.

The inconsistent bearings may be due to the presence of more than one atmospheric low or more than one source of the microseisms. While it is true that dominant microseisms from the stronger source may persist, there is that expectation that the earth particle represented by the seismometer would respond to the resultant effect of the forces acting simultaneously and not display a selective action. It would, therefore, seem that the bearing determined under such conditions would be in serious error of the true bearing of the storm from the station.

The Two Component Method. — The possibilities of the two-component method were first investigated at the Diliman Station in 1949 and was repeated in 1951.

In the vault room two seismometers were oriented at right angles to each other; one with its free end oriented in the direction of the true north, the other with its free end due east. Attempts were made to equalize their magnifications. Actually, however, the North-South component (East orientation) was found to be 1. 13 times smaller than the East-West component (North orientation) by comparison of their records when the North-oriented seismometer was turned parallel to the East-oriented one. Since the magnification curves for the instruments are not linear, this magnification ratio was used only as an approximation, the actual magnification being unknown.

Double amplitudes, i. e., amplitudes from crest to trough, were measured to the nearest tenth of a millimeter and periods were measured to the nearest tenth of a second.

A formula suggested by Dr. Del Rosario, Director of the Weather Bureau and another by Dr. Lin of the Department of Mathematics, University of the Philippines, were tried in determining the bearing by this method. Both formulas started on the assumption that the motion of the earth particles traces an ellipse whose major axis is in the direction of the dominant force, or the barometric low. From the equations of motion $x = A \sin \theta$ and $y = B \sin (\theta + \varphi)$ where $\theta = 2 \pi t / T$ and φ = *phase difference,* the following formulas, in terms of the parameter of time, were obtained :

a. $\tan 2 \theta = \dfrac{-B^2 \sin \varphi}{A^2 + B^2 \cos 2 \varphi}$, *The value of* θ *obtained from this equation is substituted in the formula :*

$$\tan \beta = \frac{x}{y} = \frac{A \sin \theta}{B \sin (\theta + \varphi)}$$ (Dr. C. del Rosario)

b. $\tan 2 \beta = \dfrac{2 A B \cos \varphi}{A^2 - B^2}$ (Dr. Lin)

In the above formulas, β is the angle through which the ellipse must be rotated to coincide with the coordinate axes. The bearing is in the quadrant containing the component with the larger amplitude. Thus, if the N-S component is larger, the bearing would be β (or $360^\circ + \beta$ if β is negative) and if the E-W component is larger, the bearing would be $90^\circ - \beta$. However, several difficulties were encountered in the application of these formulas to determine the bearing of a storm. The amplitudes as determined may be in error by as much as 20% as the actual magnifications of the instruments were unknown. The periods were not equal in the two components for the same wave, making the determination of the phase difference difficult, and lastly the phase difference itself, measured in seconds, varied over a large range of values so that the average obtained might not be representative of the true dominant phase difference.

The bearings as obtained in the formulas were at times leading and at other times lagging but the determination of the octant containing the bearing of the synoptic fix was found to be unquestionably reliable.

The Ratio Method. — In this method, three reporting stations are necessary for its utilization. At present there are two such stations, one in Diliman and a second in Guam. Already some microseisms between Diliman and Guam have been computed although they are still too scanty to warrant the drawing of lines. Assuming that micro-ratio lines could be established between the two stations, the lack of a third station would only place a storm on any of these lines without any definiteness of position. The need, therefore, for a third micro-station in the Pacific Area strategically located relative to the Philippines and Guam is very imperative if the micro-ratio method is to be availed of.

IV. *Bibliography of articles and memoirs published from 1951 to 1953.*

1. — *Preliminary Seismic Bulletin.* A Bi-monthly publication of the Weather Bureau.

2. — *Final Seismic Bulletin*. A Monthly publication of the Weather Bureau.

TECHNICAL PAPERS

1. — ALCARAZ (Arturo) and KINTANAR (Roman), Pacific Microseisms.
2. — KINTANAR (Roman), A Study of Diliman Storm Microseisms.
3. — MINOZA (Wellington), The Diliman Microseismic Research Project.

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PORTUGAL

RAPPORT NATIONAL POUR LA PERIODE DE 1951 A 1953

1. — *Liste des observatoires séismologiques en fonctionnement, appareillage utilisé.*

Pendant les années de 1951 à 1953 ont fonctionné les stations séismologiques suivantes :

a) *Porto* ($\varphi = 41° 08'$ N, $\lambda = 8° 36'$ W, alt = 96 m), avec deux séismographes Omori-Bosch de 100 kg. de masse, et un séismographe Agamennone de trois composantes, la verticale avec masse de 50 kg. et les horizontales avec masses de 80 kg. Ces appareils sont à enregistrement mécanique et ne possèdent pas d'amortissement. En 1953 a été acheté un Sprengnether vertical d'enregistrement photographique.

b) *Coimbra* ($\varphi = 40° 12'$ N, $\lambda = 8° 25'$ W, alt = 140 m), avec deux séismographes Wiechert, l'un horizontal avec masse de 1.000 kg, l'autre vertical avec masse de 80 kg, les deux à enregistrement mécanique. A la fin de 1953, on essayait de substituer l'enregistrement mécanique du séismographe vertical par l'enregistrement galvanométrique. Publie un Bulletin trimensuel.

c) *Lisbonne* ($\varphi = 38° 43'$ N, $\lambda = 09° 09'$ W, alt = 77 m), avec deux séismographes Wiechert, l'un horizontal de 1.000 kg, l'autre vertical de 1.300 kg); et avec un Mainka (450 kg de masse, composantes NS et EW), tous à enregistrement mécanique. A la fin de 1953 a été installé un séismographe Sprengnether vertical de courte période (1,5 sec.) avec pendule Favag compensée type H12; cet appareil a commencé à fonctionner en 1954. Publie un Bulletin bimensuel.

d) *Ponta Delgada (Iles Açores)*, avec un séismographe Bosch-Omori de 25 kg (composante NS). On a élaboré un projet pour la construction d'un nouvel édifice où on pense installer un jeu de séismographes électromagnétiques de courte période qui doivent entrer en fonctionnement en janvier 1956.

e) *Angra do Heroismo (Iles Açores)*, ($\varphi = 38° 39$ N, $\lambda = 27° 14'$ W), avec un séismographe Bosch-Omori de 25 kg (composante EW), et un Milne-Shaw avec masse de 0.450 kg (composante NS). Cette station expédie par voie aérienne, pour le Bureau International de

Séismologie de Strasbourg et pour le U. S. Coast and Geodetic Survey de Washington les premiers éléments des séismes avec distance épicentrale inférieure à 5.000 km; et publie un Bulletin trimensuel.

f) *Luanda (Angola, Afrique Occidentale Portugaise).* Il n'y a pas d'instruments à Luanda, mais on prétend construire dans les environs de cette ville un observatoire géophysique avec une section de séismologie.

g) *Lourenço Marques (Mozambique, Afrique Orientale Portugaise),* $\varphi = 25° 58'$ S, $\lambda = 32° 36'$ E), avec un séismographe Wiechert de 80 kg (composantes NS et ES, enregistrement mécanique). Il y a le projet d'acquisition de nouveaux appareils.

h) *Macau* ($\varphi = 22°$ N, $\lambda = 104°$ E), possède aussi un petit séismographe de modèle ancien.

2. — *Enquêtes macroséismiques; étude de séismes ressentis.*

Les enquêtes macroséismiques et études de séismes ressentis faits pendant la période de 1951-1953 ont été celles des séismes des Açores du 26 juin 1952, par A. A. de Mendonça Dias (voir Bibliographie).

3. — *Travaux de recherches : Séismologie théorique et appliquée; géographie séismologique.*

Les travaux publiés pendant cette période sont ceux de M. T. Antunes, A. A. de Mendonça Dias et Raul de Miranda mentionnés dans la Bibliographie. Le premier présente une extension de la théorie de Wenner de l'enregistrement galvano-métrique. Celui de Mendonça Dias s'occupe des séismes des Açores du 26 juin 1952, avec des conclusions sur les endroits de l'Ile de San Miguel où le sol se meut avec plus d'intensité relative, sur la tectonique de l'Ile, et avec des considérations sur les bâtiments anti-séismicité d'Angola et de Mozambique.

4. — *Bibliographie des articles et mémoires publiés de 1951 à 1953 :*

a) Antunes (M.T.), Les séismographes électromagnétiques et l'enregistrement conforme des mouvements du sol. *Bull. de la Soc. Portug. des Sci. Naturelles,* III, 2ª, S. (Vol. XVIII), 68 à 84, 1950 (paru en 1951).

b) Mendonça Dias (A.A.), Os sismos de 26 de Junho de 1952 e a sismicidade da ilha de S. Miguel. *Mémórias, Serviço Meteorológico Nacional* (du Portugal), Tomo I - RT 113, MEM 18, 27 Out. 52.

c) De Miranda (Raul), A sismicidade de Angola nos anos de 1943-1944. — Angola e Moçambique, a sismicidade das duas colónias no ano de 1945.

5. — *Recherches et publications sur la Physique de l'intérieur de la* Terre.

On n'a pas réalisé de recherches de ce type.

SUÈDE

SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR IN SWEDEN 1951-1953

1. — *Seismological stations and bulletin work*

Uppsala. The 1.000 kg Wiechert horizontal seismograph has been in continuous operation. The new short-period vertical instrument (type Grenet-Coulomb) was installed in December, 1951, and has since then been in continuous operation. In February, 1952, the University of Uppsala received a grant of 55000 Swedish Kr. (approximately 10600 American Dollars) from Knut and Alice Wallenberg Foundation, Stockholm, in order to acquire a complete set of Benioff reluctance seismometers. Drawings for these instruments were kindly supplied by Professor H. Benioff personally already in the spring of 1951. The three seismometers and the recording apparatuses have been made at Elektrisk Malmletning Co., Stockholm. This work was finished in November, 1953, and the whole set with six daily records (three components, long and short period) is expected to be in operation from the spring of 1954.

Starting in October, 1951, preliminary bulletins were issued by air mail, on a bigger scale than hitherto. They are ten-day bulletins and were first sent to 20 institutions, from May, 1952, to 30, and later to about 35 institutions in all parts of the world. Starting in May, 1952, P phases are regularly reported by telegraph to USCGS, Washington. Starting in January, 1953, recorded earthquakes within a distance of 5000 km are reported immediately by air mail to Bureau International de Séismologie, Strasbourg. In addition the yearly, printed bulletins have been issued to approximately 250 institutions.

Kiruna. Since the establishment in July, 1951, the station has been in continuous operation. The instruments are Galitzin seismographs with all three components and a short period vertical seismograph, type Grenet-Coulomb.

All records are sent weekly to the Seismological Laboratory, Meteorological Institute, Uppsala, where they are immediately analysed. The measurements are reported by air mail in a preliminary bulletin always sent together with the preliminary bulletin from Uppsala. Yearly, printed bulletins have been issued to the same addresses (approximately 250) as the yearly bulletin for Uppsala. Starting in January, 1953, the seismograph tender at Kiruna is sending telegraphic reports of P phases to USCGS, Washington.

The Science Research Council (« Statens Naturvetenskapliga Forskningsrad »), Stockholm, has paid the salaries for two assistants at the Seismological Laboratory at Uppsala for the work with the analyses of the Uppsala and Kiruna records. The same Council has also contributed to the printing costs for the yearly bulletins, and given grants necessary for instrumental development.

Skalstugan. In June, 1953, the University of Uppsala received a grant of 38144 Swedish Kr. (approximately 7400 American Dollars)

for the building and instrumentation of a new seismograph station at Skalstugan in the county of Jämtland. The situation is approximately at 63° 35' N, 12° 17' E. The station house will be built in the summer of 1954. This station will be operated by the Seismological Laboratory at Uppsala where also the records will be analysed.

Lund. No report obtained.

2. — *Seismological research.*
Seismological Laboratory, Meteorological Institute, Uppsala.

The investigations of microseisms started in 1947 have continued. The possible importance of microseismic barriers in Scandinavia was investigated and it was shown that there were no barriers along or outside the Norwegion coast. A comparative study of microseismic periods at Uppsala, Bergen, Copenhagen, and Helsinki showed among other things a more rapid extinction of the shorter periods. A comparison of the microseisms in Greenland, Iceland, and Scandinavia showed that the conditions for microseism generation may be quite different even within a relatively limited area. The microseismic time lag has been interpreted as mainly due to the delay in the arrival of cold air and higher ocean waves.

An investigation has been made of the earthquakes in Fennoscandia (Sweden, Norway, Finland), especially for the time interval 1891-1930. The macroseismic observations have been used for study of energy relations, time and space variations of the seismicity, relations to the land upheaval after the last ice age etc.

T phases from submarine earthquakes between Jan Mayen and Spitzbergen have been found on the short-period vertical records at Kiruna. Their investigation conclusively proves that the T wave has propagated as a sound wave through the ocean.

The properties of the elastic waves Lg and Rg along Euroasiatic paths have been investigated mainly by means of the Uppsala Wiechert records. Velocities, periods, amplitudes, energies, regional characteristics, transmission problems have been studied.

On a visit for study and research at the Seismological Laboratory in Pasadena (thanks to a grant from Sweden-America Foundation, Stockholm) M. Bath investigated especially compression and dilatation of P waves at Pasadena and Huancayo and a method for determination of earthquake magnitude from the vertical component of surface waves. The above-mentioned study of microseismic time lag was also made in Pasadena.

Swedish Geological Survey (« Sveriges Geologiska Undersökning »), Stockholm.

Dr. K. E. Sahlström has continued the compilation, study, and publication of data on felt shocks in Sweden. During the years 1951-1953 only the following three shocks have been felt within Sweden.

1952, December 27, around 22 h. GMT; in the vicinity of Nordingrå in the county of Angermanland on the coast of the Gulf of Bothnia; intensity IV (Rossi-Forel) over an area of 1000 km^2.

1953, March 6, 21.44.08 GMT; epicentre within Norwegian territory at 60° 14' N, 10° 55' E; magnitude = 4 (determinations by M. Bath). This earthquake was felt in the neighbouring parts of Sweden, i. e. in western Värmland and northern Bohuslän over an area of about 14000 km². The intensity did not surpass IV within Sweden.

1953, November 11, 22.30 GMT (Uppsala recorded (P) at 22.31.20); in the counties of Medelpad and southernmost Angermanland close to the coast of the Gulf of Bothnia; area about 5000 km²; maximum intensity IV.

3. — *Research in the Physics of the Earth's Interior.*

Swedish Museum of Natural History, Department of Mineralogy, Stockholm.

Professor F. E. Wickman has started a program for radioactive age determinations. Hitherto the work has been concentrated to the methods of chemical analyses. Eight minerals have been analysed for lead, uranium, and thorium.

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SUISSE

RAPPORT NATIONAL SUR L'ACTIVITE DU SERVICE SEISMOLOGIQUE SUISSE

1951-1953

Stations : En Suisse, les sismographes universels des Observatoires de Zürich, Neuchâtel, Coire et Bâle ont été constamment en service. La station auxiliaire du Collège de Brigue (Valais), équipée de sismographes de Mainka (135 kg.) et de Wiechert (80 kg.) dut être suspendue, faute de personnel.

Observations macrosismologiques : C'est la Station centrale de Zürich qui, comme par le passé, rassembla et mit au net les valeurs des observations macrosismiques. Au total, 75 tremblements de terre furent notés par la population sur le territoire suisse; dans 5 cas, il s'agissait des rayonnements de foyers situés dans les pays limitrophes (plaine du Pô, fossé du Rhin et Forêt-Noire). Les foyers situés en territoire suisse n'engendrèrent que des secousses locales d'intensité maximum V FR. C'est à nouveau dans le Valais que l'activité se manifesta le plus, en majeure partie par des répliques (35) du tremblement de terre du 25 janvier 1946 en Valais central (Montana). Enfin, une série de 12 secousses locales furent perçues d'octobre à décembre 1953 dans le Val d'Illiez (Valais), où des sources de 28° C jaillirent d'un jour à l'autre dans l'épicentre, avec un débit d'environ 1 300 litres à la minute. (Bibliographie Mariétan, I.)

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E. WANNER (Zürich).

TCHECOSLOVAQUIE

LES ETUDES SEISMOLOGIQUES EN TCHECOSLOVAQUIE DE 1951 A 1953

1. *Service séismologique*

Quatre stations séismologiques sont actuellement en fonctionnement dans le territoire de Tchécoslovaquie : Praha (station centrale), Cheb, Hurbanovo et Skalnaté Pleso. L'appareillage utilisé est le suivant :

Praha : Wiechert horizontal 1.000 kg (Ctes NS, EW), Wiechert vertical 80 kg, Anderson-Wood (Ctes NS, EW).

Cheb : Mainka 450 kg (Cte NS), Belar-Zlatorog (Cte EW), Anderson-Wood (Cte EW).

Hurbanovo : Mainka 210 kg. (Ctes NS, EW).

Skalnaté Pleso : Wiechert horizontal 200 kg (Ctes NS, EW).

Dans le courant de l'année prochaine, une station nouvellement établie à Prûhonice près de Praha (en remplacement de la station centrale) commencera l'enregistrement avec l'appareillage suivant :

3 séismographes Galitzine (Ctes NS, EW, Z) et 2 séismographes Anderson-Wood (Ctes NS, EW).

Les inscriptions de toutes les stations sont dépouillées à la station centrale à l'aide d'une méthode uniforme. Les résultats préliminaires de cette station sont présentés sous la forme des bulletins décadaires destinés à une information rapide des grands observatoires. Des résultats revus et complétés par des informations relatives à la position

de l'épicentre, profondeur du foyer, magnitude, etc., sont publiés comme Bulletin mensuel individuellement pour chacune des stations et envoyés à 90 stations étrangères. Plusieurs révisions et analyses additives précèdent la publication du Bulletin séismique annuel qui est le même pour toutes les stations du réseau et passe en revue, autant que possible, des données informatives les plus complètes et des caractéristiques numériques qui pourraient être utilisées dans plusieurs directions. On y ajoute les distances et azimuths des séismes que l'on a déterminés à l'aide des coordonnées des épicentres.

2. — *Travaux de recherches.*

a) *Ondes élastiques.*

On a étudié théoriquement la propagation des ondes élastiques excitées par un choc du type $f(t) = \sigma t^{\nu} e^{-\alpha t}$ dans un solide élastique homogène et isotrope. Une attention toute particulière a été portée à l'examen de la loi de la diminution des amplitudes à proximité de l'origine. En outre on étudie les ondes superficielles sur une discontinuité interne et la réflexion et réfraction des ondes sphériques sur une surface plane de séparation.

b) *Théorie des séismographes.*

Les recherches théoriques sur le mouvement du séismographe sous l'influence du choc ont été étendues sur les séismographes électromagnétiques en considération particulière des séismographes du type Galitzine et Benioff. Pour un mouvement du sol du type $At^{n}e^{-\lambda t}$ on a déduit des relations utilisables à la détermination de l'amplitude réelle de la première phase.

c) *Hodochrones locales.*

Par une méthode numérique on a dérivé les hodochrones locales, relatives à la station de Praha pour les ondes P, PP, S, SS et on les a comparées aux hodochrones par Jeffreys-Bullen, Gutenberg-Richter et aux hodochrones locales pour Uppsala, Zagreb et Hamburg. Les résultats font l'objet d'une communication présentée à la 10e Assemblée.

d) *Séismicité.*

Pour l'étude de la séismicité du territoire tchécoslovaque on cherche une méthode convenable pour la détermination des magnitudes des séismes proches. On prépare un catalogue détaillé des tremblements de terre ressentis en Tchécoslovaquie.

e) *Séismes proches, explosions.*

On a examiné le tremblement du 20 février 1951, ressenti en Hongrie et dans la Slovaquie du Sud. On a déterminé les hodochrones des ondes Pn, Px, P*, $\bar{P}$, Sn, Sx, S*, $\bar{S}$ et on a obtenu pour les vitesses des ondes respectives, les valeurs de 8,14; 7,87; 6,21; 5,62; 4,53; 4,35; 3,78 et 3,38 km/sec. La profondeur de la discontinuité de Conrad a été détermine à 9 km et celle de la discontinuité de Mohorovicic à 35 km.

On a construit d'une manière analogue les hodochrones pour les

explosions sur le territoire de la Bohême. Les résultats font l'objet d'une autre communication, présentée à Rome.

f) *Microséismes.*

A base des inscriptions de la station Praha on a examiné le mécanisme de l'agitation produite par le vent. En outre on étudie des corrélations entre l'agitation microséismique à Praha et les facteurs météorologiques. Les résultats de cette étude seront aussi présentés à la 10e Assemblée.

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3. Bulletin séismique préliminaire de Cheb, par V. Kárník, J. Nykles, J. Vanek et A. Zátopek (une fois par mois).
4. Bulletin séismique préliminaire de Hurbanovo, par V. Kárník, J. Nykles, J. Vanek et A. Zátopek (une fois par mois).

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UNION OF SOUTH AFRICA

REPORT ON SEISMOLOGY AND ASSOCIATED SCIENCES

FOR 1951-1953

1 — *Seismology.*

Seismograph stations and their equipment :

Grahamstown : 33° 18.6' S, 26° 34.5' E. Benioff S. P. vertical with short and long-period recorders.

Hermanus : 34° 25.5' S, 19° 13.5' E. 2 Milne Shaw horizontals.

Kimberley : 28° 45.1' S, 24° 46.8' E. Benioff S. P. vertical.

Pietermaritzburg : 29° 37.2' S, 30° 23.8' E. Benioff S. P. vertical.

Pretoria : 25° 45.2' S, 28° 11.4' E. Benioff S. P. vertical.

Union Observatory, Johannesburg: 26° 10.9' S, 28° 04.5' E. 200 kg Wiechert horizontal.

The second of these stations (Hermanus Magnetic Observatory) publishes its own quarterly bulletin. The last issues no bulletin on earthquakes. Data from the other four stations are issued monthly from the address below on behalf of the Geological Survey Office of the Union of South Africa.

Researches : These have been confined mainly to the study of earthquakes in southern Africa, most of which have been of a minor character. Work on crustal structure has been done making use of the rockbursts which occur frequently on the Witwatersrand.

Publications :

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2. — *Subsurface Radioactivity.*

During the period under review, the Geological Unit of the Atomic Energy Board, using specially designed equipment, made radiometric logs in nearly one hundred separate boreholes sunk by gold exploration companies in the Transvaal and Orange Free State, to depths up to 8200 feet. Study of these logs showed regular variability in the radioactivity as between various zones in the sedimentary succession of the upper part of the Witwatersrand system, and led to suggestions regarding the stratigraphic correlation of various conglomeratic zones in the successions encountered in the gold fields of the Orange Free State, Klerksdorp and the Western Rand.

Publications :

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3. — Correlation by Means of Radioactivity Logging, etc. *Trans. Geol. Soc. S. Afr.* 55, 1953, pp. 33 et 133.

3. — *Temperature Gradient and Heat Flow.*

A considerable amount of work has been, and is being, done on the measurement of temperature in boreholes and the determination of the conductivity of the cores. Borehole temperatures in a group of holes were measured in association with (2) above, and an attempt made to show the effect of geological structure on temperature.

Publications :

1. MOSSOP (S. C.) and GAFNER (G.), The Thermal constants of some rocks from the Orange Free State. *Jour. Chem. Met. Min. Soc. S. Afr.*, Oct. 1951, p. 61.

2. BOUWER (R. J)., Measurement of borehole temperatures, etc. *Trans. Geol. Soc. S. Afr.* 55, 1953, p. 89.

4. — *Gravity.*

The gravity survey « Stage B » of the Union of South Africa was continued by officers of the Geological Survey during the period 1951-53. Routes were observed in Natal, Eastern Province, North-Western Cape and British Bechuanaland. It is intended to publish a gravity contour plan of the Union shortly.

Hales and Gough (Measurements of gravity in Southern Africa 1950) proposed that the reduction of the gravimeter observations mentioned in the paragraph above should be carried out using tables of the effect of the topography and compensation in zones 18 to 1 plus the effect of the compensation in zones A to O at all inter-

sections of degree and half degree circles of latitude and longitude in the area covered by the observations. Tables for this purpose are being prepared by the Trigonometrical Survey Office of the Union in collaboration with Hales and Gough. These tables are almost complete and a start has been made on the isostatic reduction of the gravimeter observations.

5. — *Tectonophysics.*

During the period under review Hales has published two papers in which estimates are made of the stress-differences in a cooling Earth. The stress-differences increase more rapidly in relation to the strength at depths of 100 to 600 km than in the crust and it is suggested that it is failure at these depths which is responsible for the formation of ocean deeps.

Publications :

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ETATS-UNIS

SEISMOLOGICAL ACTIVITIES IN THE UNITED STATES

July 1, 1951 to June 30, 1954

Report to the International Association of Seismology and the Physics of the Earth's Interior through the American Geophysical Union. Prepared by the Section of Seismology, Ross R. Heinrich, President.

Foreword

This three year interval has been a period of expansion of activity in seismological research. Along with an increase of centers of action there was a tendency toward integration and re-evaluation of ideas in certain specific realms of seismology. This tendency toward orientation was shown by the large number of symposia held during the period. The subjects of the symposia themselves serve to indicate some of the trends of especial interest. In addition to the established methods of support a large amount of seismology research reaching fruition stage during this time received assistance from the

Office of Naval Research and the Geophysics Directorate of the United States Air Force.

Some cross fertilization of ideas and effort between the pure and applied aspects of seismology was achieved by participation of individual seismologists in meetings and functions of the American Geophysical Union, the Seismological Society, the Society of Exploration Geophysicists, the American Institute of Mining and Metallurgical Engineers, and the American Society of Civil Engineers.

The chief printed sources for general information continued to be the *Transactions of the American Geophysical Union, Bulletin of the Seismological Society, Earthquake Notes,* and various publications of the United States Government, although pertinent material could be found on occasion in other journals, such as the *Bulletin of the Geological Society,* the *American Journal of Science, Geophysics, Science,* and others.

In addition to the United States Coast and Geodetic Survey, the Jesuit Seismological Association, the Pasadena Seismological Laboratory of the California Institute of Technology, the University of Washington at Seattle, Washington, John Carroll University, Cleveland, Ohio, and the United States Navy Microseismic Research Project, which have submitted the institutional reports contained herein, there was a large amount of research in seismology executed at other institutions which should be mentioned here.

At Columbia University in New York investigations of Mantle Rayleigh waves, Lg, Rg and T waves, microseisms, ultra long period seismographs, and model experiments have been performed under the direction of Maurice Ewing.

In Los Angeles the Institute of Geophysics of the University of California has conducted investigations of seismic surface waves, model seismology, and theoretical problems in interpretation for an elastic earth under the supervision of Louis B. Slichter.

Thos. C. Poulter and his associates of the Stanford Research Institute have been continuing a project on the analysis of seismic waves generated by firing explosive charges in the air above the surface. This method has been applied to measurements of the thickness of the ice on the Greenland Cap in the vicinity of Thule with some very excellent results.

Father Joseph Lynch, S. J., and his assistants at Fordham University have been engaged in a project on two second microseisms recorded at several experimental stations which indicates the Great Lakes as a source for the microseisms recorded. Some results and future aspects of this research will be presented by Father Lynch in a report at this assembly of I.U.G.G.

At the Observatory of the University of Michigan at Ann Arbor James T. Wilson has continued research on travel times and crustal structure near the station and on surface waves and microseisms.

Questions raised by the character of seismic waves generated by explosions have been studied at several centers: at Harvard Uni-

versity under the direction of L. Don Leet where the character of earthquake generated surface waves and explosion generated surface waves is being studied, and by Dr. Tuve and his staff of the Department of Terrestrial Magnetism of the Carnegie Institution who will report on some of their results at this assembly of I.U.G.G.

Engineering Seismology

June 26-28, 1952 a symposium on « Earthquake and Blast Effects on Structures » was held in Los Angeles, California. The meeting was sponsored by the Earthquake Engineering Research Institute and the University of California. Papers and discussions on motion of earthquakes, blast forces on structures, analysis of structural response, properties of structures and materials, earthquake effects on structures, blast effects on structures, and earthquake provisions of building codes have been published in a volume of proceedings of the Institute, available from the Department of Engineering, University of California, Berkeley 4, California.

On September 11, 1952 a symposium on « Seismology as it Applies to the Design of Structures » was sponsored by the American Geophysical Union in Chicago, Illinois. Captain E. B. Roberts of the United States Coast and Geodetic Survey was chairman of the meeting which included six formal papers of engineering seismology interest. Some of the ideas expressed at this symposium have been published in the *Transactions of the American Society of Civil Engineers of 1952* (vol. 117, pp. 716-780) in a report of the Joint Committee of the San Francisco, California, Section of A.S.C.E. and the Structural Engineers Association of Northern California. John E. Rinne served as Joint Committee Chairman.

The interest in engineering seismology in the United States during this three year period might be exemplified by many other illustrations; for example, the report by Frank Neumann on «Earthquake Intensity and Related Ground Motion» published by the University of Washington Press; the special number 2B of volume 44, pp. 201-462, of the *Bulletin of the Seismological Society of America* in April, 1954 on « An Engineering Study of the Southern California Earthquake of July 21, 1952 and its Aftershocks » by Karl V. Steinbrugge and Donald F. Moran; and the session on March 27, 1954 at the annual meeting of the Seismological Society in which seven papers on engineering seismology were presented.

Microseisms

A very significant symposium on microseisms was held at Arden House, Harriman, New York, September 4-6, 1952. This meeting was sponsored jointly by the Office of Naval Research and the Geophysical Research Division of the United States Air Force. The formal program was organized by Dr. R. C. Gibbs of the National Research Council, and Dr. Perry Byerly served as moderator.

The symposium brought together about thirty-one of the currently active investigators in microseisms from the United States and abroad. The meetings were very much stimulated by the discussions of presented papers. The papers and discussion were edited by James

T. Wilson and Frank Press and published by the National Research Council. Dr. Byerly noted that the purpose of the symposium was to broaden the minds of the members—not to offer each an opportunity to convert the others. As one member remarked, after many years observing microseisms at one station one may learn pretty well with what to correlate them. But this does not mean that he would be equally successful in another geographic locality. It would even appear that microseisms in Europe and America are not so comparable as we might expect.

During this interval many articles on various aspects of the microseism problem were published in the journals.

Other Symposia

The use of seismological data in the interpretation of the earth's interior was brought out in a symposium on the interior of the earth which was held at the spring meeting of the American Geophysical Union in May, 1953.

Model studies in geophysical research became more prominent during this period and at the May, 1954 meeting of the A.G.U. a symposium on geophysical models was held. Two papers on seismic models were presented. The paper by Frank Press and Jack E. Oliver described the model studies at the Lamont Geological Observatory of Columbia University and a report on this work will be presented during this Assembly of the I.U.G.G. A paper by L. Knopoff of the Institute of Geophysics of the University of California on three-dimensional seismic models was also given. Simple models of usually less than 60 mm. maximum dimension and compressional waves of a half and two centimeters with various materials were used by Knopoff. Results for refraction and reflection were obtained, with the influence of boundary conditions on the wave forms of reflections being of special interest.

Seismograph Station Changes

During this period many United States stations modified or changed their instruments. In December, 1953 the station at the University of South Carolina, Columbia, South Carolina, installed a three component Wilson-Lamison set of seismometers, two long-period horizontals (8 seconds) and a short period (1.2 seconds) vertical.

A number of new seismograph stations were started. A complete list of United States stations appears in the *Comptes Rendus des Séances de la Huitième Conférence,* Oslo, p. 139, and additions and changes were published in the *Comptes Rendus des Séances de la Neuvième Conférence, Brussels,* p. 277.

On July 27, 1951 a temporary station with a vertical component short period Benioff seismograph was installed by the U. S. Coast and Geodetic Survey at Nelson, Nevada. The coordinates are 35° 42½' north latitude, 114° 49½' west longitude.

A new seismograph station at Fayetteville, Arkansas was established in August, 1951 at the University of Arkansas. Dr. George V. Cohee is director of the station which is equipped with a vertical

component short period Benioff. The coordinates of the station are 36° 05.46' north latitude, 94° 11.47' west longitude.

In 1953 a seismograph station was installed at the University of North Carolina at Chapel Hill, North Carolina. Two long period Sprengnether horizontal seismometers operate at periods of seven seconds. The coordinates of the station are 35° 55' north latitude, 79° 03' west longitude. . The director of the station is Gerald R. MacCarthy.

In 1953 a seismograph station was established at Southern Methodist University at Dallas, Texas. The director of the station is John A. Harrington.

Recently the United States Coast and Geodetic Survey in cooperation with the University of Minnesota, Duluth Branch, installed a Benioff short period vertical at Duluth. The coordinates are 46° 49.2' north latitude and 92° 05.0' west longitude. The director is Dr. Howard B. Hanson.

The station changes in the Pasadena group are given below in the Pasadena report.

Significant United States Earthquakes

Among the significant earthquakes in the United States during this period are the following :

On August 15, 1951 an earthquake centered near Terminal Island off San Pedro, California, causing sub-surface damage to oil wells exceeding two million dollars.

On April 9, 1952 an earthquake was felt over a large area of the great plains states of Oklahoma, Kansas and Nebraska. The earthquake centered in central Oklahoma near the southern terminus of the Nemaha Uplift, a buried geologic feature which seemed to exert a strong influence on the felt area. Although the earthquake was felt in seven states, only minor damage was caused in the vicinity of the epicenter.

On July 21, 1952 an earthquake centered in Kern County, California, which resulted in eleven deaths and property damage over ten million dollars. Damage was greatest at Tehachapi and Arvin, California. Landslides were common and three tunnels of the Southern Pacific Railroad were severely damaged. There were many aftershocks. The strongest, on August 22, caused two deaths. The estimated total damage for the series of shocks was fifty million dollars. Additional information on these earthquakes is contained in the Pasadena report below.

UNIVERSITY OF CALIFORNIA, BERKELEY, CALIFORNIA

Perry Byerly

A number of special seismological problems have been receiving attention, and the following points should be mentioned.

Jack F. Evernden has made a study of Rayleigh waves using both the four stations about San Francisco Bay as a tri-partite network and the three Galitzin seismographs at Berkeley to get the nature of the motions. He finds that the Rayleigh waves are made

up of a number of groups of pure Rayleigh waves, but not all coming along the great circle arc. This is particularly the case for South American earthquakes in which some of the groups have been refracted out under the Pacific and returned from the Pacific to the stations about San Francisco Bay.

Jerry Eaton has written a thesis on the theory of the short-period Sprengnether seismometers and developed a method for getting the constants, including the reaction of the galvanometer on the seismometer.

The writer has been especially working on the following three problems :

a) The station at Fresno in the great valley of California is on deep alluvium and records from Coast Range earthquakes show several groups of Love and Rayleigh waves of speed less than 1 km per second with periods of three or four seconds. These waves travel principally in the alluvium. A temporary station will be installed to trace them more thoroughly.

b) A station was established at Reno, Nevada to find out if P_n waves from coastal earthquakes were delayed in their arrival by the root of the Sierra Nevada, even as they are delayed at the Owens Valley stations. The Sierra near Owens Valley is very high and it is conceivable that there would be a root (i.e., a protuberance below the Mohorovicic discontinuity, which is normally at a depth of 30-35 kms in California).

It has been found that the P_n waves are delayed at Reno. The Sierra is still high enough near Lake Tahoe to have a root. This settles the problem as to whether the Sierra mass is entirely granitic or partly basalt. It must have considerable basalt under the granites in order to produce a root. This follows from isostatic balancing with Raitt's Pacific structure and the general California structure as determined by Byerly and by Gutenberg.

c) On the seismograms of West Indian earthquakes recorded at stations on the Atlantic Seaboard the writer has identified a wave which comes in 12-35 seconds after P as a wave which travelled in the water (like a T wave) for some tens of kilometers near the source and then into the land.

JOHN CARROLL UNIVERSITY, CLEVELAND, OHIO

Henry F. Birkenhauer, S. J.

During the calendar year 1953, 205 earthquakes were reported in the John Carroll Seismological Bulletin.

A Sprengnether visible recorder was installed. A slight modification of the circuit was made by Mr. Carome for the more efficient recording of the time marks, and satisfactory records are obtained.

During the year 1953 the observatory continued its program of vibration analysis, studying progress waves generated by quarry blasts and tunnel excavations, as well as the vibrations in structures caused by rotating machinery. About seventy-five percent of the vibration analysis work was in the latter category.

A paper, « Case Histories of Vibrational Studies » summarizing several unusual vibrational problems, was presented by the writer at the May, 1953 meeting of the American Geophysical Union. Studies are being made at the observatory with a view to determining an index of damage to machinery from vibrations, similar to the work carried on by the U. S. Bureau of Mines and published in 1942.

THE SEISMOLOGICAL LABORATORY OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY AT PASADENA

Prepared by the Laboratory Staff

Station Development

Stations in operation as of March, 1954 are as follows :

	φ	λ	h
Pasadena	34°08.9'	118°10.3'	295 m
Mt. Wilson	34 13.5	118 03.4	1742
Riverside	33 59.6	117 22.5	250
Palomar	33 21.3	116 51.6	1700
Santa Barbara	34 26.5	119 42.9	100
China Lake	35 49.0	117 35.8	766
Haiwee	36 08.2	117 57.9	1100
Tinemaha	37 05.7	118 15.5	1180
Barrett	32 40.8	116 40.3	510
Big Bear	34 14.3	116 54.8	2060
Dalton	34 10.2	117 48.6	523
Fort Tejon	34 52.4	118 53.7	980
Woody	35 42.0	118 50.6	500
King Ranch	35 19.7	119 44.7	670
Isabella	35 38.6	118 28.6	760

Other sites were in operation temporarily during 1952 in Kern County, California. The station at LaJolla was discontinued in July, 1952. All stations are equipped with at least one short period vertical component Benioff seismograph having recording drum accuracy of approximately $\pm$ 0.1 sec., with chronometers, and with automatic recording of radio time signals several times per day. In addition, at Pasadena, Tinemaha, Barrett, and China Lake long period galvanometer recorders are operated.

Instrument Development (H. Benioff)

(1) Development of vertical and horizontal component capacity transducer seismographs has been completed. These are arranged to operate galvanometers as well as magnetic tape recorders and ink or heated stylus visible writing recorders. (2) A two-component ultra long-period strain seismograph has been completed having a galvanometer of 180 seconds period and equivalent magnification of about 20. This combination has recorded waves in the Kamchatka earthquake of November 4, 1952, having periods of 55 minutes, and a single pulse lasting more than six hours. (3) An earth strain

meter similar to the strain seismograph has been set up in a tunnel situated in the mountains in Dalton Canyon. This instrument, provided with a fused quartz indicator rod, is equipped with a direct optical recorder; it responds to secular and tidal strains as well as those arising from seismic waves. (4) A long period vertical component seismograph is being developed. It has a period of 10 seconds with 10 fold overdamping (electromagnetic) and capacity transducers having an output proportional to the pendulum displacement. (5) A 100 kc quartz crystal clock has been developed using a temperature controlled quartz crystal with a Wang magnetic flip-flop counter for providing time signals of one second duration once per minute. The accuracy of this clock is approximately within one tenth second per week.

Investigation of Wave Types

Seismograms of body transverse and surface waves written by pendulum seismographs have been compared by H. Benioff and B. Gutenberg with those recorded by strain seismographs. According to theory, this comparison should provide information differentiating Rayleigh waves from Love waves and SV from SH waves. Results based on this procedure have been published. Benioff has shown that under special conditions the source waveform of earthquakes can be derived from simple recorded wavelets. A number of such wavelets have been observed having forms predicted by Ricker. This indicates that the source may be a step function, a spike or a spike doublet.

Studies of a number of phases with paths traversing the core have been carried on by students as theses for the degree of doctor of philosophy. Additional information on low velocity layers in the outer part of the earth's mantle have been derived by Gutenberg from studies of travel times and amplitudes at distances up to 20°. These results have been based in part on studies of waves recorded from artificial explosions in California. Waves identified as reflections from the Mohorovicic discontinuity and a shallower level have been studied on earthquake seismograms by B. Gutenberg; corresponding phases have been found in blast recordings from prospecting and station instruments by G. Shor. Seismograms from surface sources in the Pacific region have provided the basis for improvement of travel time curves.

Seismic Sequences (H. Benioff)

The sequence of shallow earthquakes which began April 11, 1925 in the Indian Ocean $\lambda = 58°$ E, $\varphi = 34°$ S exhibited an elastic strain-rebound characteristic of the form $S = a + b \log t$. The occurrence of large shocks ceased on October 23, 1933 for an interval of some 16 years. Assuming that strain was accumulating during this quiescent interval at the rate given by the equation, it was possible to predict the magnitude of any large shock which might occur. Thus on December 8, 1951 the accumulated strain was equal to a 7.5 magnitude earthquake and on that date a shock of this size occurred.

Benioff has continued his study of seismic sequences in relation to crustal structure and orogeny. Evidence from these studies

indicates that the principal orogenic structure responsible for each of the great linear and curvilinear mountain ranges and oceanic trenches is a fault. The faults occur either wholly within the oceanic realm or else marginal to the continents. Oceanic faults extend from the surface to depths of 350 to 700 km, the majority falling in the 600 to 700 km depth range. They exhibit an average dip of 60°. Their elastic strain-rebound characteristics show that these faults are composed of two separate mechanical units, a shallow component extending from the ocean bottom to the Mohorovicic discontinuity, which in the vicinity of the fault may be depressed to approximately 60 km, and a deeper component extending from the Mohorovicic discontinuity to the 700 km crustal boundary. The marginal faults occur in dual and triple forms. The dual faults comprise a shallow member extending from the surface to the depressed Mohorovicic discontinuity and an intermediate member extending to a depth of 200-300 km. The average angle of dip is 32° The marginal triple form is similar to the dual down to the 300 km level. At this depth the angle of dip changes abruptly to 60° to form a third component extending to the 650 ± km crustal boundary. The elastic strain-rebound characteristic of the marginal faults indicate that the components of these structures also move as separate units, although the two lower elements exhibit evidence for mechanical coupling.

Kern County Earthquakes

The principal shock of magnitude 7.6 to 7.7 occurred 1952 July 21, $11^h52^m14.3^s$ GCT at 35° 00'N, 119°02'W, on the White Wolf fault. The epicenters of this and the larger aftershocks are probably accurate within 5 kilometers and the origin times within less than 0.5 second. To supplement the routine stations a portable seismograph was operated successively at several strategic locations. Four continuously recording special stations were installed. Epicenters and origin times of the aftershock sequence have been determined by Richter and assistants. To the end of 1953, 208 shocks of magnitude 4 and over have been recorded with many more smaller ones. On January 12, 1954, a shock of magnitude 5.9 occurred with an epicenter close to that of the principal shock.

H. Benioff finds that shocks originating SE of the fault trace form a compressional strain release series of the form $a + b \log t$, whereas those on the NW side form a shear series of the form $A + B\,[1-\exp(-at^{\frac{1}{2}})]$. The onset of the shear series was 37 hours after the principal shock. Depths of most of the larger shocks, including the principal shock, were near 16 km, the usual depth for this region. A few were shallower. The geographic distribution of the aftershocks indicates that faulting during the principal shock extended approximately 60 km NE along the White Wolf fault from the epicenter. The only foreshock (July 21 09^h43^m GCT, magnitude 3.1) originated somewhat more to the west than the principal shock. Using initial recorded motions measured on seismograms collected from all parts of the world, Gutenberg finds that the initial slip occurred on a reverse fault dipping SE approximately 63° from the horizontal. Using a new method involving transverse waves, he also

finds that the initial slip was nearly due north in the south-east block. He finds that magnitudes computed from body waves are nearly independent of azimuth of the recording station, whereas those computed from surface waves in the principal shock (not in the aftershocks) exhibit a large variation with azimuth, being approximately one magnitude greater in the direction of Europe than in the opposite direction. H. Benioff has pointed out that such a pattern should result from a progression of slip along the fault in the direction indicated by the aftershock distribution.

The delay of Pn attributed to the « Root of the Sierra » is confirmed by C. F. Richter. In the main shock the delay of Pn for paths under the Sierra Nevada Mountains relative to the arrivals along other paths was approximately 3 to 4 seconds to Reno, Tinemaha and Haiwee. Gutenberg finds that magnitudes of large aftershocks, determined by the original Richter method from maximum trace amplitudes recorded by torsion instruments, agree within a quarter unit with those determined from amplitudes of distant body waves and surface waves.

A method in which the seismicity of a region is indicated by a smoothed system of contours is being applied by P. St. Amand to the aftershock sequence.

Publications referring to the preceding reports are listed in « Progress Reports of the Seismological Laboratory » for 1951, 1952 and 1953, appearing in the *Transactions of the American Geophysical Union*.

INSTITUTE OF TECHNOLOGY OF SAINT LOUIS UNIVERSITY AND CENTRAL STATION OF THE JESUIT SEISMOLOGICAL ASSOCIATION, SAINT LOUIS, MISSOURI

Ross R. Heinrich

During this period there were various researches at the Institute, and the results of some of those have been published or will be published shortly.

Motions of P and S waves recorded at the Florissant and Saint Louis stations were studied. The studies show a preferential direction of motion in the recordings of certain earthquakes from selected regions : the Aleutian Islands, South America, and Mexico.

Neumann's method of S-wave analysis was applied by Heinrich and Haill to Saint Louis records of Aleutian Islands earthquakes and by Daniel H. Walsh to Mexican earthquake seismograms. In the latter case the computed azimuths of the initial horizontal shears at the origin were found to parallel the major structural trends of the Mexican Coastal regions with rather close accuracy.

1. Northwest shift of the southwest side of faults striking northwest-southeast for the region north of about 17° N latitude.

2. Southwest shift of the southeast side of faults striking northeast-southwest for the region south of about 17° N latitude.

This interpretation seems to add evidence to Shepard's hypothesis of the extension of the San Andreas type faulting into the Gulf of California and to indicate a further extension of this type to faulting along the Mexican Pacific Coast to about 17° N latitude.

Otto Nuttli has been reworking the data on first motion of the western Washington earthquake of April 13, 1949. He has also completed a study of the seismic P wave in the shadow zone. He notes that the P curve appears to be branched. The second branch, called P_2, begins at about ninety degrees and is linear. Its slope is approximately 4.688 seconds/degree arc. The other portion, called P, becomes linear at about 100°. Its slope is 4.439 seconds/degree arc. From the slope of the linear part of the P curve the depth to the core of the earth was found to be 2901 kilometers. From the slope of the P_2 curve it is suggested that at a depth of about 2700 kilometers there is a zone of decreasing velocity. The zone should be less than ten kilometers in thickness. The decrease in velocity is very small, from about 13.65 to 13.61 kilometers per second.

M-waves from 51 earthquakes recorded at Saint-Louis and Florissant were investigated by Frank F. Pilotte. It was found that the M-waves have only longitudinal and vertical components of motion and that the particle motion is retrograde elliptical. It is believed the phase can be adequately explained by existing Rayleigh wave theory.

The mean group velocities of M for an all oceanic and an all continental path were found to be 3.48 km/sec and 3.07 km/sec respectively.

Travel time tables for M have been constructed taking into account not only the total distance travelled but also the per cent of oceanic path, and the first period of the phase.

Lees Burrows has applied the Richter Magnitude Scale to Florissant seismograms using ultimately the method of Markus Bath on the vertical Galitzin records.

Patrick Heelan, S. J., has published his thesis on the theory of elastic head wave propagation along a plane interface separating two solid media in two issues of *Geophysics* and Pierre Honnell has described his electromechanical transducer system for the transient testing of seismographs in the same journal.

Henry Miller, S. J., is preparing a report for publication on the Central Oklahoma earthquake of April 9, 1952 based on a study of seismograms.

Carl Kisslinger has published his results on the effect of variations in chemical composition on the velocity of seismic waves in carbonate rocks. The variations of velocity in limestone have not fallen into as definite a pattern as might be expected. The possibility that the concentration of magnesium carbonate may appreciably alter the velocity in limestone was investigated. A volume for volume replacement of calcite by dolomite tends to increase the velocity but

dolomitization giving rise to local porosity, whether the resulting interstices are empty or filled by non-carbonate tends to decrease the velocity.

During the interval the Institute has continued its program of study of seismic waves generated by blasts.

Harry Hasenpflug and Edwin Ginzel have examined many records of dynamite blasts at the Alpha Quarry near Saint Louis. Records were obtained on the Wood- Anderson seismographs at Saint Louis and Florissant, the Reeff short period seismographs installed at the Saint Louis station in 1953, the TMV portable vertical seismograph, and the three component portable Sprengnether seismograph. These studies at this quarry furnish additional evidence of the association of relatively high amplitude and low frequency with unconsolidated overburden, and relatively low amplitude and high frequency on bed rock with rapid attenuation of high frequency in thick unconsolidated alluvium for a constant distance observation site. Most interesting of all, the results have shown an increase in the amplitude of the Rayleigh wave with increase of the depth of shot hole.

The problems of microseisms and micro-oscillations in the atmosphere have received a great deal of attention.

Daniel Walsh has finished a report on short period microseisms near Saint Louis which will be published shortly. His observations show that

> In the records of the Wood-Anderson seismographs, the small very regular, group microseisms of nearly constant period less than one second appear in discrete sections or storms commencing with a rather steady increase to maximum displacements and concentration of activity and finally returning either gradually or abruptly to quiescence. By a consideration of gross hourly occurrences, times of storm beginning and ending and of maximum trace displacements, as well as an investigation of many individual cases, a distinct correlation in time is shown to exist between these short period microseisms at Florissant and increased short period microbarographic activity recorded by the Macelwane instrument at the same station.
>
> A survey of only the six hourly surface synoptic maps reveals that the great majority of the 155 arbitrarily chosen microseismic storms may be associated either with the approach and/or passage at the station of a cold frontal type discontinuity or with local, non-frontal convective activity. Warm fronts and barometric highs and lows near the recording station are apparently unrelated to this band of microseisms.
>
> Indeed, a nearby high seems to hinder the generation or dampen the activity of these microseisms. Although the activity usually persists longer in the post- than in the pre-cold frontal period, a study of these microseisms may be useful in predicting cold frontal passages over land. Toward this end, an attempt is made to distinguish frontal from non-frontal microseismic storms on the basis of their recorded characteristics.

Evidence is presented which seems to indicate that these correlated short period microseisms and micro-oscillations are real phenomena, that they are not related as cause and effect, but that they may proceed from the same source. This study suggests that, with more precise information, combined analyses of these microseisms and micro-oscillations may be quite useful in elucidating the local turbulent nature of the atmosphere.

The study of local earthquakes in the middle Mississippi Valley has continued. The program to interpret the tectonic relations of epicenter locations was advanced during this period by a series of detailed auxiliary geophysical surveys with magnetometer and gravimeter on the northeastern flank of the Ozark Highlands. These surveys have indicated new structural trends in the basement which may help to explain some of the heretofore apparently incongruous epicenter locations.

The station members of the Jesuit Seismological Association remained the same as reported at the Brussells meeting in 1951.

During the period 1951-1954 there have been some extensive changes in personnel and operating procedures of the Central Station which have resulted in unavoidable delays in the publication of Preliminary Bulletins. It is hoped that current reorganization will facilitate the scheduling of bulletins.

THE UNIVERSITY OF WASHINGTON, SEATTLE, WASHINGTON

Frank Neumann

In January, 1953 Howard Coombs published a summary of Washington earthquakes. In September, 1953, Frank Neumann, former seismologist of the U. S. Coast and Geodetic Survey, succeeded E. E. Vesanen and J. W. Jones as Director of the University of Washington seismograph station. On February 1, 1954 the University Press published the new director's report on « Earthquake Intensity and Related Ground Motion» .

In addition to establishing auxiliary stations in the Puget Sound area, an intensive study of Washington earthquakes will be made in the light of new information revealed in this report.

THE PENNSYLVANIA STATE COLLEGE, STATE COLLEGE, PENNSYLVANIA

B. F. Howell, Jr.

The Division of Geophysics and Geochemistry operates a seismographic observatory with three Galitzin type seismometers recording three components of motion. Only rarely do members of the staff make investigations of individual earthquakes. During the past year one of the students has been studying the minor seismic

activity in the vicinity of Sinking Springs near Reading, Pennsylvania.

The bulk of the seismological research of this Division is directed at an investigation of the nature of seismic pulses produced by explosions. The principal aims of this project are to determine the manner of transmission of seismic waves in nonelastic media such as earth, to find out how the features of a pulse of seismic energy are effected by variations of the properties of a transmitting medium, and to discover in what manner such transmission depends on the amplitude and frequency content of the initial pulse.

It has been shown already that such transmission is closely related to that of elastic waves, but differs from it in that pulse shape is not preserved, frequency composition changes rapidly, and dispersion and absorption of energy are great. Recent work has yielded measurements of the rate of attenuation of direct and refracted compressional waves, coupled waves, and a combined group of Rayleigh and Love waves in the weathered surface layer at two locations near State College. Approximate figures of the energy content of each of these pulses have also been obtained.

Studies are also being completed on the effect of depth of burial of the charge on the seismic energy generated and of the effect of stemming on the amount of seismic energy radiated.

Mr. George V. Keller has just finished a thesis on the nature of the dispersion of the seismic waves from explosions. He concluded that existing theory is adequate to explain the principal features of the seismic waves from explosions, including all or a large part of the coupled waves. The theory of dispersion developed by Sezawa and his associates, particularly as related to the M_2 root of the general equation for surface waves, appears adequate to describe almost all of the observations, provided the complicated layered nature of the surface rocks is taken into account.

It appears from Mr. Keller's study that it takes several wave lengths for the surface waves to be thoroughly developed, and at short distances they travel in a thinner layer than is the case several wave lengths from the shot point.

Another student is currently working on a photoelectric analyzer to speed up the frequency analysis of seismic pulses. With it we hope to gain much more information on the frequency content of recorded pulse, and on the variation of the rate of attenuation with frequency. We are also carrying out studies to determine the relative effectiveness of mechanical impact as compared to the detonation of explosions in generating seismic waves of low intensity.

SUMMARY OF SEISMOLOGICAL WORK OF THE U. S. COAST AND GEODETIC SURVEY JULY 1, 1951 - JUNE 30, 1954

Teleseismic Program

The Coast and Geodetic Survey operated 8 seismograph stations during the period of this report. This includes a vertical component

Benioff seismograph installed at Nelson, Nevada late in 1951. Of the cooperative stations, Bureau of Reclamation stations at Pierce Ferry and Overton were discontinued June 30, 1952, the equipment later instrumenting independent stations at Boulder, Colorado and Duluth, Minnesota respectively; and the Shasta station was transferred to the University of California net. The Columbia University assumed control of the Bermuda station. Cooperative stations were established at Fayetteville, Arkansas and Montezuma, Chile. A total of 15 cooperating stations remain.

The early location of 1995 earthquakes from airmail and telegraphic reports during the three year period was made possible through the cooperation of about 100 foreign and domestic stations. The year 1952 was noteworthy because of the heavy swarms of earthquakes in Hokkaido, Japan, March 4; Kern County, California, July 21; and Kamchatka, November 4. The program of exchanging teleseismic readings has now developed to the extent that the limiting factor in expanding the epicenter program is no longer the availability of data but time to process them. To expedite epicenter determinations, a very old but highly accurate 36 inch globe was obtained on an indefinite loan through the courtesy of the American Geographical Society, New York. Quarterly Seismological Bulletins for 1946, 1949, and 1950 were completed and beginning with January 1954, the Bulletins are being issued up to date on a monthly basis. The annual publication « United States Earthquakes » through 1952 has been completed.

Macroseismic Program

Questionnaire and on-the-site investigation of earthquake effects in the United States continued to be carried on with the cooperation of several thousand volunteer reporters. 6156 questionnaire reports from 743 earthquakes were received during the three year period. 78 of the earthquakes had an intensity V or greater on the Modified Mercalli Scale. Of these, 13 had intensity VII or greater, including one of intensity VIII and one of intensity IX to XI.

The Kern County, California, earthquakes of July 21, 1952, and its many aftershocks, taxed the resources of the Bureau. Experienced personnel were on site within hours after occurrence, investigating field effects and installing temporary seismographs. This earthquake was the strongest in the United States since the April, 1906 California shock, and is among the 10 strongest in the history of the country. It killed 12 persons and injured many more and caused more than $ 50 million damage in Kern County alone. Landslides blocked state highways and several railroad tunnels were destroyed. The last named effect is the reason for assigning an intensity XI to a small area in the epicenter region. This earthquake was accompanied by a change in levels over a range of several miles of about 4 feet, and about 2 feet in horizontal displacement. The aftershock of August 22, 1952, centered near Bakersfield, Calif., was the strongest aftershock. It killed 2 persons, injured 30 and caused

widespread damage to buildings and other structures. A pictorial report of the Kern County earthquake is being prepared.

Strong-Motion Program

70 strong-motion seismographs are scattered over the Western United States and 7 in Central and South America. These include recently installed accelerograph or accelerograph - displacement meter units, viz., 2 at Cachuma Dam, California near Santa Barbara, and 1 each at Taft, California; Portland, Oregon; Tacoma, Washington; and Ross Dam, Washington. The station at Seattle was relocated to better ground. Accelerograph units are being equipped to record also displacement in 2 or 3 directions. During the 3-year period, 373 strong-motion records of 87 earthquakes were obtained. Accelerograph and displacement meter records of the July 21, 1952 earthquake were significant because they demonstrated that ground displacement may be measured instrumentally, permitting rapid interpretation of the records.

Instrumental Development

Small displacement meters intended for mounting on an accelerograph chassis and recording on the same drum, with stable periods as high as 7 or 8 sec. have been developed. Available instruments will equip about half of the accelerographs.

An inexpensive, short-period, moving coil, vertical seismometer and an inexpensive intermediate period horizontal seismometer have been developed. These instruments are now in successful operation at 7 stations.

A horizontal shaking table was designed and constructed and a vertical shaking table, borrowed from the Geological Survey was modified to fit the needs of the Bureau. These tables are driven by electromagnetic transducers. The amplitude and frequency of table motion can be varied through a wide range by means of a commercial ultra-low frequency oscillator.

An electronic multi-purpose 3-component vibration meter was purchased for field use.

A split-beam photocell galvanometer repeater was designed for the purpose of transmitting seismic signals across a long line or for driving ink recording galvanometers. Two such recorders are now in the Department of Commerce building and others are being used in the Seismic Sea Wave Warning System.

Seismic Sea Wave Warning System

This work continued in successful operation. It received a dramatic workout on November 4, 1952 when a submarine earthquake near the Kamchatka Peninsula generated large waves which were transmitted to the farthermost regions of the Pacific basin. The cooperating seismograph stations reported the earthquake, tide stations reported and detected the actual sea waves, and the point

of origin and the travel time to Hawaiian Island points were estimated, all within two or three hours after the occurrence of the earthquake.

Research

Integration of the accelerograph records of the Puget Sound earthquake of April 13, 1949 was completed as far as that could be done. Serious difficulties were encountered which prevented satisfactory results from being obtained.

Integration was also applied to a number of accelerograph records of ground motion, of which displacement meter records had likewise been obtained. Comparison of the integration results with the displacement meter records demonstrated that for most purposes the displacement meter is superior to integration as a means for obtaining displacement information.

The widespread coverage of North America by seismographs under the control of the Coast and Geodetic Survey made possible a study of origins of microseisms and the relative microseismic absorption rates by the continents and oceans, using the records on file in the Washington Office. It was found that if microseisms are attributed to a storm at sea, the direct source is an effect of the storm rather than the storm itself, and that the absorption rate of parts of the ocean is relatively high.

Considerable progress was made in the investigation of (1) the series of Kamchatka earthquakes occurring during the month of November 1952, (2) the velocity of earthquake waves from Alaskan earthquakes across the Canadian shield to stations in northeastern United States, and (3) the examination of earth tides to determine the triggering effect upon earthquakes.

Cooperative Activities

Captain Elliott B. Roberts was a delegate to the VI Consultation of the Commission on Cartography of the Pan American Institute of Geography and History which met at Ciudad Trujillo, Dominican Republic in October 1952.

Mr. Frank Neumann of the Washington Office at the request of the Haitian government conducted an on-the-spot survey of the epicentral area of destructive Haitian earthquakes during October 1952.

The Seismological Field Survey made available its facilities and otherwise cooperated in the meetings of the Advisory Committee on Engineering Seismology and the Earthquake Engineering Research Institute. It also maintained close liaison with other professional organizations on the West Coast interested in engineering-seismology problems.

The Survey continued cooperation with the Bureau of Reclamation in operating seismograph stations at Boulder City, Nevada, and Hungry Horse, Montana, and reactivated the seismograph station of the Smithsonian Institution at Calama, Chile. The interpretation of seismograms and publications of results by the Survey continued

with fourteen university and privately operated stations in the United States.

Requests for seismograms to be used in research projects were heavy. Among the leading organizations that borrowed records were the Seismological Laboratory at Pasadena; Lamont Geological Observatory, Palisades, New York; Saint Louis University; Rome Observatory; and the University of California, Berkeley.

The Survey served as consultant to the Central Water and Power Research Station in Poona, India relative to the study of ground motion at a dam installation. Visiting seismologists from the India Meteorological Department and the Quetta Observatory, Pakistan Meteorological Service spent several months studying and observing the methods and procedures of Survey seismological work.

Personnel

Captain Elliott B. Roberts continued as Chief of the Geophysics Division in Washington. Dr. Dean S. Carder succeeded Frank Neumann, who retired August 1953, as Chief of the Seismology Branch in Washington. Mr. Leonard M. Murphy continued as Chief of Earthquake Information and as Assistant Chief of the Seismology Branch. William K. Cloud was appointed Chief of the Seismological Field Survey in San Francisco to succeed Franklin P. Ulrich, who died July 2, 1952.

Nota : Le Rapport national des Etats-Unis est accompagné en annexe d'un mémoire intitulé : « Microseisms used in Hurricane Forecasting » prepared by Mr. Marion H. Gilmore, Geophysicist, U.S. Navy Microseismic Research Project, U.S. Fleet Westher Central, Miami, Florida. Ce mémoire sera publié dans le fascicule N° 19 des Publications du Bureau central séismologique international, Série A, Travaux Scientifiques.

YOUGOSLAVIE

RAPPORT NATIONAL DE L'ACTIVITE SEISMOLOGIQUE POUR LA PERIODE 1951-1953

Généralité. — Le territoire de la République de Yougoslavie englobe les territoires des 6 républiques composantes, à savoir : Serbie (Beograd), Croatie (Zagreb), Slovénie (Ljubljana), Bosnie et Herzegovine (Sarajevo), Crna Gora — « Montenegro » — (Titograd) et Macédoine (Skopje).

1. Observatoires séismologiques. — Sur le territoire de la Yougoslavie n'existent momentanément que deux observatoires séismologiques, à savoir :

Serbie : *Beograd* (44° 19' 17,2" N, 20° 27' 19,2" E Gr. H = 128,658)
et
Croatie : *Zagreb* (45° 49' N, 15° 59' E Gr. H = 135 m).

a) L'Observatoire (Institut séismologique) de *Beograd* dispose d'un bâtiment spécial analogue p. ex. à ceux de Hambourg et de Strasbourg; depuis l'année 1896, les séismographes à enregistrement mécanique sont en service :

— Wiechert astatique composantes horizontales NW et NE, masse 1.000 kg, et
— Wiechert vertical à masse de 1.300 kg,
— deux composantes EW et NS Mainka S.O.M. à masses de 450 kg.

b) En Croatie : *Zagreb* (Institut Géophysique 45° 49' N, 15° 59' E Gr. H = 155 m); les séismographes installés dans un bâtiment spécial sont des types suivants :

— Wiechert astatique, masse = 1.000 kg, compos. horizontales;
— Wiechert vertical, masse 1.300 kg, et
— un petit Wiechert astat. compos. horiz. à masse de 80 kg.

c) A l'issue de l'année 1953, le Gouvernement de la République de Macédoine a décidé, sur l'initiative de l'Institut de Beograd, d'organiser une station séismologique à *Skopje* (41° 59' N, 21° 24' E Gr.).

2. Enquêtes macroséismiques, etc. Chaque phénomène macroséismique quelconque est soumis au contrôle de la part de l'Institut séismologique de Beograd sur le terrain même de l'épicentre. Chaque phénomène macroséismique est le sujet d'une étude géologique pour avoir une idée sur les causes éventuelles en se basant sur la constitution géologique de l'épicentre et de la surface ébranlée. D'un cas à l'autre, l'Institut de Beograd dirige ses membres sur la région épicentrale pour vérifier les renseignements de ses collaborateurs du territoire. Dans les cas exceptionnels, le soussigné se trouve lui-même à l'épicentre pour observer le développement du phénomène.

3. Travaux de recherches séismologiques. — Les personnes qui ont séjourné dans la région épicentrale préparent des rapports détaillés. De tels travaux de recherche sont du domaine de la séismologie appliquée.

4. Bibliographie des articles et mémoires publiés de 1951 à 1953. Dans la période de 1951 à 1953 incl. ont été publiés en Yougoslavie les articles à savoir :

1951

MIHAILOVIC (J.), La région séismique du lac de Scutari. *Annales Géologiques de la Péninsule Balkanique*, t. XIX, pp. 203-213, Beograd.
— Les régions séismiques en Macédoine. *Bulletin de l'Institut géologique de la République Macédoine*, fasc. 2 (pp. 1-157), Skopje
— Régions séismiques du lac de Scutari. *Monographies de l'Institut séismologique de Beograd,* n° 1, pp. 1-74, Beograd.

MIHAILOVIC (D.), Catalogue des tremblements de terre Epiro-Albanais. *Archive de l'Institut séismologique de Beograd*, n° 1, Beograd.

MIKINCIC (Vjekoslav), *Bulletin Géologique.* Publication de la Direction fédérale du Service Géologique, Beograd.

1952

MOKROVIC (Josip), Zagreb. Les hodochrones de Zagreb des ondes séismiques pour les tremblements de terre des profondeurs normales. — Die Hodochronen von Zagreb für seismische Raumwellen und Erdbeben normaler Tiefen. *Institut Géophysique : « Les travaux »*, III[e] sér., n° 2, Zagreb 1952.

1953

MIHAILOVIC (J.), Die seismische Dynamik der Balkan-Halbinsel. *Bulletin d'information de l'U.G.G.I.* News Letter, 2, n° 2, avril 1953, Paris.

— La séismicité de la région du lac de Scutari. *Geofisica Pura e Applicata,* Milano, vol. XIV.

— Die seismische Dynamik der Balkan-Halbinsel. *Ann. Géol. de la Péninsule balkanique*, t. XXI, pp. 231-235, Beograd.

Remarque. — En outre des publications imprimées ci-dessus citées il existe dans l'Institut séismologique de Beograd, attendant l'occasion d'être imprimés, deux grands mémoires sur les deux grandes régions séismiques de la Serbie centrale, celle de Sumadia (pp. 1-400 dactylographiées) et de Morava (pp. 1-330). Ces deux régions de la Serbie centrale ont présenté chacune deux ou trois grands tremblements de terre, à savoir : Sumadia le 22 mars 1922 (Bukulja) et 15 mai 1927 (Rudnik), la région de Morava le 10 octobre 1879 (à l'île Moldava du Danube) et le 8 avril 1893 (région Resava). Les deux mémoires sont accompagnés de nombreuses photographies, esquisses, tableaux, chronologie, etc.

5. Les recherches géophysiques. — Pour les recherches géophysiques en général il existe en Yougoslavie un Institut Géophysique auprès de la faculté technique de l'Université de Beograd qui se consacre à des problèmes géophysiques spéciaux : recherches des dépôts de naphte, de charbon et de matières premières industrielles, métallurgie, etc. Il existe même une direction fédérale du Service géologique qui publie un Bulletin géologique. Quant aux questions séismologiques, l'Institut séismologique de Beograd manque de collaborateurs pour la séismologie pratique, p. ex. pour définir l'épicentre des diverses secousses, pour calculer la magnitude des grands séismes, pour définir la profondeur de l'hypocentre, etc.

Une grande difficulté dans les recherches séismologiques provient des changements fréquents de l'état de l'Institut de Beograd même : p. ex. la première organisation du service séismologique de Serbie a été établie en 1906 comme une section séismologique de l'Institut géologique de l'Université de Beograd; plus tard, en 1919, il a été organisé comme Institut séismologique propre de l'Université de Beograd, en 1953 comme Institut séismologique du Ministère de l'Enseignement et des cultes de Yougoslavie. Le 1[er] janvier 1949, il a été désigné comme Institut central séismologique de Yougoslavie et enfin, le 24 janvier 1951, il est devenu Institut séismologique du Gouvernement de la République de Serbie. Ce dernier changement a empêché l'organisation des stations séismologiques projetées, à savoir celles de Sarajevo (Bosnie et Herzégovine), Titograd (Crna Gora) et Skopje (Macédoine).

Une autre difficulté pour les recherches séismologiques modernes provient du manque de collaborateurs compétents en tectonique géo-

logique et en calculs séismologiques modernes. L'Institut séismologique de Beograd publie régulièrement son Bulletin séismique mensuel et l'échange avec toutes les institutions séismologiques du monde. De son côté, l'Institut géophysique de Zagreb a décidé, à partir de l'année 1953, de publier ses renseignements annuels propres macroséismiques et microséismiques concernant le territoire de la Croatie.

Beograd, 30 avril 1954.

Prof. J. MIHAILOVIC,
Directeur de l'Institut séismologique de Beograd.

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Société Nouvelle d'Impression MUH - LE ROUX

45, rue du Fossé-des-Treize, STRASBOURG

Dépôt légal : 1er trimestre 1956 N° d'ordre de l'imprimeur : 1096

National Report for Canada

SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR

for

INTERNATIONAL UNION OF
GEODESY AND GEOPHYSICS
ASSOCIATION OF SEISMOLOGY
AND PHYSICS OF THE
EARTH'S INTERIOR
TENTH GENERAL CONFERENCE
ROME, ITALY, 1954

compiled by J. H. HODGSON
DOMINION OBSERVATORY, Ottawa
Chairman, the Sub-Section on Seismology
and Physics of the Earth's Interior
Associate Committee on Geodesy and Geophysics
National Research Council, Ottawa, Canada

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INTRODUCTION

The National Committee for Canada operates through a number of Subcommittees. The work of three of these Subcommittees is related, wholly or in part, to the Association on Seismology and Physics of the Earth's Interior. These are:

Seismology (Dr. J. H. Hodgson, Chairman)
Gravity (Dr. M. J. S. Innes, Chairman)
Radioactivity and Heat Flow (Professor A. D. Misener, Chairman)

There is no Subcommittee on Tectonophysics, but Professor J. T. Wilson, who is very active in this field, reports to the Committee on matters relating to this subject.

Each of the above named Chairmen have submitted detailed reports on the work of their Subcommittees, and these have been compiled by the author, whose principal function has thus been an editorial one. All the Chairmen will be present at the Meetings and so able to take part in any discussions concerning their particular field of interest.

Since the Brussels meeting of the Union some personnel changes have taken place which should be noted. Mr. A. H. Miller who was for many years Chief of the Gravity Division, Dominion Observatory, retired from the Government Service in 1951. Mr. Miller was responsible for the establishment of most of the pendulum stations so far observed in Canada and carried out fundamental research in gravity and magnetic methods of geophysical prospecting. He was active in field work up until the time of his retirement and is still occupied in preparing the results for publication.

Dr. E. A. Hodgson, former Chief of the Seismological Division, and Assistant Director of the Dominion Observatory, also retired in 1951. Dr. Hodgson was for many years Secretary of the Canadian Committee for the U.G.G.I., and was more recently Chairman of the Subcommittee on Seismology. The present network of ten Canadian seismograph stations were set up under his direction, and he had the satisfaction of arranging for the re-instrumentation of most of these stations before his retirement.

The Geological Survey of Canada suffered a severe loss through the death, in October 1952, of Dr. H. V. Ellsworth. Dr. Ellsworth was an authority on the chemistry and mineralogy of radioactive minerals. His early work in radioactive age determinations did

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much to stimulate other work of this sort in Canada. At the time of his death he was head of the Radioactive Resources Division of the Survey.

At a recent meeting, the National Committee for Canada sent its congratulations to Professor Lachlan Gilchrist on the completion of his twenty-fifth year as a teacher of geophysics. Professor Gilchrist was responsible for organizing the Geophysics Laboratory at the University of Toronto. It must be a source of satisfaction to Dr. Gilchrist, as it is to the Committee, that the University has become one of the most active centres of geophysical instruction and research.

SEISMOLOGY

Earthquake Seismology and Field Studies

The Dominion Observatory, Department of Mines and Technical Surveys, maintains a network of ten seismograph stations across Canada. The locations of these stations, and a list of the instruments which they operate, may be found in the bulletins issued from Ottawa. It should be mentioned here, however, that in 1951 W. G. Milne was transferred from Ottawa to Victoria to set up a Western Division. At that time he installed stations at Alberni and Horseshoe Bay, British Columbia, and has since published annual reports on the earthquakes of the area (16, 17)*. It should also be mentioned that during the past three years the stations at Halifax and at Victoria have been completely rebuilt and re-equipped, while the stations at Seven Falls and Shawinigan Falls have been improved by the addition of sensitive short-period vertical seismographs.

At the moment of writing a new seismograph station is proposed, at Jean-de-Brebeuf College, Montreal. This station will be operated by the Jesuit Fathers, and will be under the direction of the Rev. M. Buist, S.J.

The rockburst travel-time studies conducted by J. H. Hodgson have been completed, and the results published (8). The field work of the Seismological Division is now under the direction of P. L. Willmore, who joined the staff in 1952. Dr. Willmore has designed a set of field seismographs in which twelve stations, covering a spread of as much as 60 miles, will transmit their outputs by short-wave radio to a central recording station where they will be recorded, side by side, on a single strip of photographic paper. The instruments will be used not only for crustal studies but also for the investigation of large scale local features, and can be adapted for work at sea without difficulty. A 3-channel prototype was used

* Numbers in parenthesis refer to items in the Bibliography which will be found at the end of the report.

during the summer of 1953 to obtain a profile of a suspected meteor crater at Brent, Ontario, and the complete 12-channel set will be used during the summer of 1954 to study a circular feature, 30 miles in diameter, in the Province of Quebec.

W. G. Milne has been carrying out crustal studies in southern British Columbia with the co-operation of the Royal Canadian Navy, who have dropped a series of precisely timed and located depth charges. The records obtained at the Victoria, Alberni and Horseshoe Bay stations indicate, in a preliminary analysis, a sedimentary layer about 1·6 km. thick with a P-wave velocity of 5·39 km./sec., underlaid by a single layer about 33 km. thick in which the velocity for P waves is 6·39 km./sec. The velocity of P waves below the Mohorovičić discontinuity is 8·17 km./sec. It should be stressed that these results are preliminary; further work is proposed.

J. H. Hodgson and several co-workers (9-14) are pressing forward with the application of Byerly's method for determining the direction of faulting in earthquakes. In order that the method may be applied to earthquakes of any focal depth and may make use of phases other than P, tables of extended distances for all focal depths for the phases of P, PKP, PcP, PP and pP have been published. The method has been applied to a total of 34 earthquakes to date. This is a suitable opportunity to thank those many seismologists who have made the studies possible by completing our questionnaires so promptly.

Engineering Seismology

The Division of Building Research, National Research Council, has recently issued a National Building Code which takes account of earthquake risks and includes an earthquake probability map. This map, which was prepared with the co-operation of the Dominion Observatory, is similar to those formerly issued for the United States by the United States Coast and Geodetic Survey. It is a first attempt and undoubtedly will have to be modified as experience is gained, but its production was made necessary by many enquiries about local seismicity. The Division is also equipped to assist engineers in the study of blast damage; this work is under the direction of Dr. T. D. Northwood.

A problem which has attracted considerable attention in Canada is that of rockbursts in mines. The earlier work of E. A. Hodgson in the gold mines of the Kirkland Lake area has been discontinued, but studies are being conducted in coal mines in Nova Scotia and on the Alberta-British Columbia boundary, by the Mines Branch, Department of Mines and Technical Surveys, working in co-operation with the mining companies and with the Nova Scotia Research Foundation. As part of its investigation the Nova Scotia Research Foundation has measured the elastic properties of coal at various

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pressures. The Dominion Observatory is assisting in the study of the western mines by maintaining three temporary seismograph stations in the area, equipped with Willmore seismographs. The purpose is to discover whether there is regional seismicity.

Laboratory Seismology

When Professor (now Sir Edward) Bullard was at the University of Toronto he initiated a program for the study of seismic problems through the use of models. This work has been carried forward under the direction of Professor C. Barnes. Piezoelectric transducers are used to emit and receive pulses which are displayed as "seismograms" on a cathode ray tube. Problems of several types have been studied.

An initial series of experiments was carried out by T. D. Northwood and D. V. Anderson. The first was the "Lamb" problem (19) dealing with propagation of tremors over the surface of a solid half space. The results obtained are in qualitative agreement with the theory of Lamb but are much more oscillatory in character. This is attributed to inhomogeneity in the concrete used as a model material. This problem is reported in most seismic model work done to date. It is difficult, even in the laboratory, to achieve the homogeneous isotropic elastic medium usually considered by the theory.

The second problem is the change of shape of pulses upon reflection via maximum or minimum time paths. This is done experimentally, using a hemispherical reflector in water (4). A source and receiver are placed side by side on the axis of the hemisphere, and the change in shape of the reflected pulse is noted as the distance from the reflector is varied. It is found that, when the reflection time is a minimum (distance less than the radius of the hemisphere), the pulse develops a tail. When the reflection time is a maximum, the pulse develops a precursor. These results are in agreement with a mathematical theory which was developed. Other surfaces studied in a similar manner included a concave paraboloid (1), plane parallel plates (2), and a cylindrical tube (3).

Professor Barnes reports that work is currently being carried out on two problems. In an endeavour to obtain a better understanding of wave propagation in porous, granular media, N. R. Paterson has developed a method for measuring velocity using crystal transducers and a variable frequency continuous wave source and has applied the technique to close packings of spherical glass beads. A pulse method is also being developed for the study of the same models. Graded sands are being investigated, and a technique for measuring velocity using high explosive caps and a thyratron timing circuit has been devised.

The other project reported by Professor Barnes is being carried out by P. N. S. O'Brien, and deals with a study of the wave critically refracted at the plane interface of two elastic media. Several authors have demonstrated analytically the existence of this wave by solving the wave equation with appropriate boundary conditions. Mostly they predict that the decay of amplitude with distance should be proportional to $r^{-\frac{1}{2}} L^{-\frac{3}{2}}$ where r is the projection on the interface of the distance between source and detector, and L is the distance the wave has travelled in the lower medium.

In order to verify this law a wax block of dimensions 120 cm. $\times$ 40 cm. $\times$ 35 cm. was held submerged in a tank of water so that the water surface was about 30 cm. above the upper face of the block. A Rochelle-salt transducer driven by a pulse generator acted as an acoustic source; a second Rochelle-salt element was used to detect the resulting acoustic field at various points in the water. Pulses about 30 micro-seconds long and 600 volts in amplitude were fed to the source transducer at a repetition rate of about 100 times per second. The voltage produced by the detecting transducer was fed, via a pre-amplifier, to a C.R.O. which was synchronized with the pulse generator. Therefore, a stationary pattern of the received pulse was obtained on the cathode ray oscilloscope and could be photographed. A 100 Kcs. signal was displayed on a second trace of the C.R.O. to give timing marks.

It was found that the amplitude of the critically reflected wave at points fairly close to the source was less than the direct wave at the same point by a factor of between 10 and 100. The experimental results for the decay of amplitude with distance agreed quite well with the above mentioned theoretical relationship.

In addition to using a wax block submerged in water, results were also obtained for water on top of concrete, and light lubricating oil on top of a saturated solution of calcium chloride.

RADIOACTIVITY AND HEAT FLOW

Radioactivity of Rocks

The study of the radioactivity of rocks, both in the laboratory and in the field, has attracted considerable attention during the past few years. At the University of Toronto H. A. Slack (46) has developed a three-channel, anticoincidence counter and has used it for further studies of the Round Lake Batholith, near Kirkland Lake, Ontario. K. Whitham (53) has developed a scintillation counter for laboratory use, capable of analysing the separate uranium and thorium content of radioactive minerals. The instrument could be readily adapted for field use.

The Geological Survey, Department of Mines and Technical Surveys, is using an airborne scintillation counter developed for them by Atomic Energy of Canada, Ltd. The counter is operated in the same aircraft as the Survey's airborne magnetometer, and is therefore normally flown at a height of about 1,000 feet. Experiments have shown that, for best results, the counter should be flown at heights of less than 200 feet. Nevertheless, at a height of 1,000 feet regional radioactivity may be determined and compiled into radiation maps.

Age Determinations

The first mass spectrometer in Canada was that built and operated by Professor H. G. Thode at McMaster University. This instrument is occasionally used on problems of geophysical interest (42, 43, 47, 48) but most such work is done on the mass spectrometer at the University of Toronto which came into operation in the summer of 1951. The instrument has been operated by C. B. Collins, R. M. Farquhar and R. D. Russell. Papers on particular aspects of the work will be presented to the Meetings by D. W. Allen and R. M. Farquhar, but Professor J. T. Wilson has provided the following summary.

"During the past three years over 100 samples of lead extracted from uranium and thorium minerals have been isotopically analysed and the results published. About 150 samples of ore leads from many sources have also been isotopically analysed. The majority of these analyses form a very uniform sequence. Both from the general geological relations of these specimens and from dates which can be assigned to particular specimens it is concluded that the sequence is a function of the age of deposition of the minerals and thus that lead ores can be dated, the older ones more accurately than younger ones.

Some of the analyses from a few localities do not fall into this uniform sequence of the "normal leads" as they contain much larger and irregularly distributed amounts of radiogenic isotopes. These leads have been classed as "anomalous". It is considered that additional studies of the isotopic ratios of leads will provide a means for dating and correlating many sulphide deposits and for discovering much about their origin and history.

Argon has been extracted from a few potassium minerals and the ratio of A^{40} to K^{40} used to date the minerals.

The following general conclusions have been reached as a result of this work on age determinations.

(a) We agree with Nier and Holmes that ages obtained for uranium minerals are most reliable when concordant ages are obtained by both chemical and isotopic analyses. Pre-

liminary measurements suggest that radon loss does not appreciably affect age determinations by the lead ratio (Pb^{207}/Pb^{206}) method for old, fresh uranium minerals, although it can lead to large errors in age determinations for young and altered minerals.

(b) *Ages calculated from the A^{40}/K^{40} ratio for potassium-bearing feldspars and micas are in agreement with those obtained by the above methods. A value of 0·089 for the branching ratio of K^{40} has been used to calculate the argon ages. This branching ratio was obtained by using radiogenic argon measurements carried out independently at two different laboratories.*

(c) *Isotopic analyses of many old lead ores can be used to date them. The ages agree with those determined for apparently contemporaneous uranium and thorium minerals. It is considered that this method can be made still more precise.*

(d) *Vein minerals, including galena, give only minimum ages, and unlike pegmatites, may be very much younger than the surrounding country rock.*

(e) *All minerals more than 2×10^9 years old have been found to come from areas underlain by rocks of Keewatin and Timiskaming types and by granites cutting them. Such areas are already known and dated in or around Ontario; Yellowknife, Northwest Territories; Uganda-Rhodesia-Transvaal; Sierra Leone; North Belgian Congo; Mysore, India; Kalgoorlie, Australia and perhaps in the Sveco-Fennidian area. They are regarded as continental nuclei. They have a different type of structure from later belts, a higher proportion of lavas, and they may have been formed when temperatures in the earth were higher than in more recent times.*

(f) *All Archean-type rocks younger than about 2×10^9 years old form belts marked by pegmatites formed during a limited range in time; they are markedly gneissic; they do not contain a high proportion of lavas and they resemble the cores of young primary mountains. The Mozambique belt is an example ($0{\cdot}5$ to $0{\cdot}7 \times 10^9$ years old). The Archean-type provinces and young mountains both form broad belts lying beside or between continental nuclei and get progressively younger at greater distances from the nuclei (e.g. Keewatin nucleus, Grenville gneissic belt and Appalachian Mountains of Eastern North America).*

(g) *The writers agree with C. K. Leith who recommended that the names Archean and Proterozoic should be used for*

"types of rocks not time", for they find that the maximum known age of some belts of Archean gneisses is much less than the minimum age of some Proterozoic-type rocks in other places. For example, the Archean-type Grenville belt contains many pegmatites all much younger (0·8 to 1·1 × 10^9 years) than the veins which cut the flat-lying Proterozoic-type rocks at Martin Lake, Saskatchewan (1·6 × 10^9 years). There seem to be similar circumstances in Africa.

(h) It is considered that the continental or sialic blocks have been built entirely in geological time, for even the present rate of extrusion of lava which has been estimated to be 1 km.^{3} per year would have sufficed to build the continents in about 4 × 10^9 years. The work of Macgregor and of Ewing in the West Indies shows that the lavas there are predominantly acid and are rising from the depths through a basaltic ocean floor to form new additions of continental composition at the earth's surface. This appears to be the commonest type of volcanic process."

Studies of Non-radiogenic Isotopes

In the last three years the investigation of natural variations in the relative abundance of the sulphur isotopes has been actively continued under the direction of Professor H. G. Thode of McMaster University. Thode and his colleagues have shown that there are no significant differences between the ratio S^{32}/S^{34} in meteorites and terrestrial igneous rocks (43). The S^{32}/S^{34} ratio in samples of native sulphur varies by as much as 4·5% depending on whether the sulphur is of organic or volcanic origin. It is now believed possible to determine the origin of sulphur deposits from the isotopic composition of the sulphur (42).

Thode has also investigated the isotopic fractionation occurring when sulphates are reduced to sulphides by sulphur bacteria under anaerobic conditions (47, 48). This process, which represents part of the natural sulphur cycle, has been reproduced in controlled laboratory experiments, and some fractionation by bacteria has actually been observed.

In the hope that the relative abundance of the silicon isotopes might reflect the geological and chemical histories of the rocks containing them, R. J. Allenby studied the isotopic ratios of silicon in a number of minerals (22). A maximum variation in the ratio Si^{28} to Si^{30} of 1·3 per cent has been detected.

An investigation of possible variations in the isotopes of titanium was undertaken by J. E. Hogg (33) for similar reasons. No variation in the Ti^{46} to Ti^{50} ratio greater than one per cent was observed.

Heat Flow

During the period under review, heat flow studies have been possible at two widely separated parts of Canada.

At Resolute Bay a number of holes were drilled in the permafrost, cores were taken at regular intervals to a depth of 650 feet and temperature elements were placed at regular intervals to the same depth. The drilling program (25, 49) was carried out through the co-operation of the Dominion Observatory, the Meteorological Division of the Department of Transport and the United States Weather Bureau. A schedule of temperature measurements were carried out by Department of Transport officers, and these, with the cores, were made available to Professor A. D. Misener of the University of Western Ontario.

In connection with their Kitimat Project, the Aluminum Company of Canada is driving a power tunnel through the mountains of the Coast Range, from Lake Tahtsa to Kemano, B.C. Measurement of temperature and of thermal conductivity are being made by company engineers and by Dr. J. H. Blackwell of the University of Western Ontario.

The observation both from Resolute Bay and at Kemano are being reduced by Professor Misener, who will report to the Meeting on the results of these studies.

Detailed investigations of the thermal properties and of the thermal history of the earth are being carried out by Professor R. J. Uffen at the University of Western Ontario and by Professor J. A. Jacobs at the University of Toronto. Combining solid-state theory, seismic data, and Bullen's density distribution, Uffen is endeavouring to determine the temperature distribution of the solid portion of the earth's interior (50-52). Jacobs has assumed a linear relationship between the reciprocal of the volume coefficient of thermal expansion and the pressure below a depth of about 1,000 km, and has derived an expression for the adiabatic temperature gradient (34-36). The results of this investigation have been applied to the question of convection currents in the core and mantle and to the problem of the transfer of heat from the core, both of which have an important bearing on Bullard's dynamo theory of the geomagnetic secular variation (37, 39). Jacobs has also studied conditions in the core and given a physical explanation as to how the Earth's inner core may have become solid (38, 40). A detailed study of the thermal history of the Earth has been carried out, and the equation

of heat conduction for a radioactive Earth has been solved numerically for a number of different Earth models by means of FERUT, the electronic computer at the University of Toronto.

GRAVITY

The field of gravity is of interest both to the Section of Geodesy and to the Section on Seismology and Physics of the Earth's Interior. It is sometimes difficult to know to which section a particular phase of the work should be reported. The Subcommittee on Gravity has submitted a detailed report to the Section of Geodesy and has made copies of this report available to the Section on Seismology. The following remarks have been selected from that larger report.

During the past three years gravimeter surveys have been carried out in Canada by the Dominion Observatory, by graduate students of the University of Toronto and Harvard University, by the Nova Scotia Research Foundation and by many commercial companies. Values from selected stations from some of the commercial work have been made available to the Dominion Observatory for reduction to the national datum to give increased coverage in certain areas. Through the combined efforts of these organizations there are more than 10,000 regional observations available, together with an additional 2,000 detailed observations in certain areas. So far the greater portion of these results are unpublished, chiefly because of inconsistencies in the values of gravity due to the uncertainty of the calibration constants of the different gravimeters employed.

These difficulties have now for the most part been eliminated. During the last three years, special emphasis has been placed in the establishment of a well connected primary gravimeter network to which all previous and future surveys can be referred (58).

Regional Surveys

(I) *British Columbia and Yukon Territory.* During the summer of 1953, in connection with a program to extend the gravimeter base network of Canada, the Dominion Observatory made gravity and magnetic measurements at intervals of five miles along the Alaska Highway. Analysis of the Bouguer anomalies and the vertical magnetic intensities have been made by C. H. G. Oldham, graduate student at the University of Toronto. He attributes negative gravity anomalies to three distinct causes: basins of sedimentary rocks, light rocks particularly granite forming part of the basement, and thickening of the crust.

(II) *Northern Canada—Precambrian Shield.* During the past three years the Dominion Observatory has observed about 600 stations in this area, bringing the total to more than 2,000. Most

of these stations lie in the unsettled regions of northern Canada and have been established using air transportation. As was reported to the Committee on Physics of the Earth's Interior at the Brussels Meetings, all areas of exposed Archean volcanic and sedimentary rocks are characterized by relatively positive gravity anomalies. Whilst most areas underlain by granite and granite gneiss are characterized by negative anomalies, there are some belt-like areas underlain by granitic rocks where the anomalies are positive. An effort is being made, through systematic sampling for density determination, to determine whether these variations originate from effects within the crust or from density variations.

(III) *Quebec.* In a co-operative program between Harvard University and the University of Toronto, supported by the National Research Council of Canada, M. Fitzpatrick observed approximately 800 stations over an area of some 20,000 square miles in Southern Quebec, between the St. Lawrence River and the International boundary.

The regional gravity picture consists of three parallel features; a negative Bouguer anomaly of −45 milligals in the St. Lawrence Lowlands region, a positive anomaly of +55 milligals coincident with the axis of the Sutton Mountain anticlinorium, and a negative anomaly of −65 milligals over the Megantic Range.

The possibility that these anomalies could be explained by variations in density of the surface rocks was examined and discarded. It was finally concluded that they are the results of crustal warping accompanied by the intrusion of ultrabasic material beneath the Sutton Mountains.

Many local anomalies were obtained, all of which can be correlated with near surface density contrasts. One of the most striking is the +55 milligals anomaly associated with the peridotites and pyroxenites of the Thetford Mines, Black Lake region.

(IV) *Ontario.* The University of Toronto has been active in carrying out gravity studies in southern Ontario. About 1,500 observations of the value of gravity have been made in different parts of Southern Ontario by R. J. Uffen, J. B. Prendergast, C. H. G. Oldham and D. B. Sutherland. Most of these lie in an area of 20,000 square miles which lies along the southern border of the Canadian Shield between Lake Huron and the Ottawa River. A similar number of density determinations have been made of the basement rocks in this area of Grenville gneisses and it has been found that locally there is a close correlation between lower density rocks and lower values of gravity. In addition there are regional trends in the gravity values which have no relation to the surface densities and these are suspected to be due to variations in the thickness of the crust.

The FERUT electronic computer at the University of Toronto Computation Centre has been employed to obtain a least squares solution for the regional effects.

(V) *Maritime Provinces.* The results of all regional gravity measurements made by the Dominion Observatory in Nova Scotia, New Brunswick and Prince Edward Island up to the end of 1950, are given and analyzed in a report (54) by G. D. Garland. The correlation of the Bouguer anomalies with the major geological structures is discussed, and it is shown that most of the anomalies may be related to the densities of known formations. In several cases, the depth extents of these formations are estimated from their gravitational effects. A rather detailed interpretation is made of the structure of the Carboniferous basin in the region of Moncton, New Brunswick.

Detailed Surveys

(I) *Sudbury Basin.* A study (60) of the gravity anomalies for about 350 stations established by the Dominion Observatory at intervals of about one mile along roads over and in the vicinity of the Sudbury nickel deposit has been completed by A. H. Miller. The correlation of the Bouguer anomalies with the major geological structures is examined and it is shown that the larger positive anomalies are associated with the older Precambrian volcanics. A gravity profile across the basin, after corrections are made for the gravitational effects of the volcanic rocks, supports the theory that the Sudbury nickel irruptive is sill-like in form and that it does not derive from a large intrusive body under the centre of the basin.

(II) *Ottawa District.* The results of an analysis by S. F. Saxof (63) of some three hundred gravimeter observations made by the Dominion Observatory covering an area of about four hundred square miles in the vicinity of Ottawa has been completed. The major features of the Bouguer anomaly field are apparently related to large scale density variations within the earth's crust, while certain of the residual anomalies could be related to the known surface geology. The most prominent of these effects were found in the case of certain major normal faults which cross the area, and which previously had been investigated with the torsion balance. Gravity observations over areas of positive magnetic anomaly showed a correlation, suggestive of the presence of denser, more magnetic phases in the Precambrian basement.

(III) *Geophysical Investigation of a Possible Meteorite Crater near Brent, Ontario.* Gravity measurements made by Dominion Observatory in the vicinity of a circular topographic depression, two miles in diameter appearing on aerial photographs, support the theory of a meteoric origin. The depressed area is nearly filled with heavy glacial deposits and there is some evidence that these deposits

are underlain by Paleozoic sediments. The gravity results show a circular minimum of 5 milligals, provide an estimate of 1,500 to 3,600 feet for the depth to the undisturbed floor, and are inconsistent with a volcanic origin for the feature. A paper on the gravity, seismic and magnetic work done over the feature will be read at the Meetings.

(IV) *Nova Scotia.* The Dominion Observatory has made a detailed gravity investigation of a section of the Cumberland Basin lying between Springhill and Malagash, Nova Scotia, for the purpose of delineating underground structure to facilitate the direction of drilling operations in the attempt to locate salt. The results were found to be of definite value in delimiting the extensions to the known salt deposit at Malagash and indicate two areas lying to the East, structurally favourable to salt accumulation.

The Nova Scotia Research Foundation has conducted a somewhat similar work over an area of about 375 square miles in Hants county and in the vicinity of Antigonish. Gravity observations have proved helpful in the study of the geology of the area.

Theoretical Studies

F. S. Grant, of the University of Toronto, has published a series of three theoretical papers the first two of which (56) deal with the three dimensional interpretation of gravitational anomalies. A method is developed whereby the derivatives of the surface field and a knowledge of the density contrast between the body and its surroundings are used for determining the approximate size and shape of the three dimensional mass distribution which is required to produce a given gravitational field.

The third paper (57) develops an analytical method based on the theory of statistical probability for separating regional from local potential field effects.

TECTONOPHYSICS

Two studies of tectonophysical interest are reported from Nova Scotia. Prof. J. E. Blanchard advises that the Nova Scotia Research Foundation is using the C^{14} method to determine the age of submerged tree stumps with a view to determining the change in elevation of Nova Scotia during the past 10,000 years. Professor H. S. Heaps, of the Nova Scotia Technical College, is studying problems of crustal loading (65).

A group at the University of Toronto, working under the direction of Professor J. T. Wilson, have made major contributions to tectonophysical studies. Wilson himself (71-76) has undertaken a general analysis of the present mountain system of the world and of

some of the past systems and shield areas, and has shown that the principal aspects of these features may be explained on the basis of Jeffreys' contraction hypothesis. Wilson advises that the fullest description of his work will appear during 1954 in a symposium on "the Solar System" being published by the University of Chicago under the editorship of G. P. Kuiper. Wilson's work will appear in Vol. II of this symposium, which will bear the title "The Earth as a Planet".

A. E. Scheidegger, has produced a series of papers (66-70) in which the physical implications and geological consequences of several proposed systems of orogenesis are examined. He has conconcluded that the best physical explanation is provided by the contraction hypothesis.

A serious objection to the contraction hypothesis has been removed by Jacobs in the work discussed earlier (39) under the heading of Heat Flow, for he has shown that thermal conditions within the earth do not require convection currents in the mantle.

The work of Hodgson and his several co-workers at the Dominion Observatory, in determining the direction of faulting in earthquakes, may be expected to provide information of interest to tectonophysicists. To date, however, too few earthquakes have been reduced to permit any definite conclusions.

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EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1954.