Comptes Rendus N° 12

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 ONZIÈME CONFÉRENCE

RÉUNIE A TORONTO DU 3 AU 14 SEPTEMBRE 1957

Rédigés par le Secrétaire Général Associé Markus BÅTH

Publié avec le concours financier de l'UNESCO

Société Nouvelle d'Impression
MUH-LE ROUX - Strasbourg
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INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

INTERNATIONAL ASSOCIATION OF SEISMOLOGY AND THE PHYSICS OF THE EARTH'S INTERIOR

BUREAU AND COMMITTEES

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

Prof. *B. Gutenberg,* Seismological Laboratory, 220 North San Rafael Avenue, Pasadena 2, California, U.S.A.

Dr. *J. H. Hodgson,* Dominion Observatory, Ottawa, Canada.

Sir *Harold Jeffreys,* F.R.S., Professor, 160, Huntingdon Road, Cambridge, England.

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FOR THE PHYSICS OF THE EARTH'S INTERIOR

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Prof. *F. A. Vening-Meinesz,* Potgieterlaan 5, Amersfoort, The Netherlands.

Gravimetric Interpretations :

Prof. *J. Goguel,* 100, rue du Bac, Paris 7, France.

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Sir *Edward Bullard,* F.R.S., Department of Geodesy and Geophysics, Madingley Rise, Madingley Road, Cambridge, England.

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

Elasticity and Plasticity :

Sir *Harold Jeffreys,* F.R.S., Professor, 160, Huntingdon Road, Cambridge, England.

Dr. *R. Stoneley,* F.R.S., 16, Millington Road, Cambridge, England.

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PRESIDENT :

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VICE PRESIDENT :

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SECRETARY :

Mr. *E. Peterschmitt,* Institut de Physique du Globe, 38, Boulevard d'Anvers, Strasbourg, France.

MEMBERS :

Dr. *M. Båth,* Seismological Laboratory, Meteorological Institute, Uppsala, Sweden.

Mrs. Dr. *I. Bóbr-Modrakowa,* Panstwowy Instytut Geologiczny, ul. Rakowiecka 4, Warsaw, Poland.

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Dr. *J. M. van Gils*, Institut Royal Météorologique de Belgique, Service séismologique, 3, avenue Circulaire, Uccle I, Belgium.

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

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

Dr. *R. P. B. Kogoj,* Observatoire de Ksara, par Zahlé, Liban, Lebanon.

Prof. *A. Kvale,* Universitetet i Bergen, Jordskjelvstasjonen, Joach. Frieles gt. 1^{II}, Bergen, Norway.

Miss *I. Lehmann,* Kastelsvej 26, Copenhagen, Denmark.

Miss Dr. *N. Pinar,* Izmir Mebusu, Ankara, Turkey.

Prof. *E. Savarensky,* Institute of Earth Physics, Academy of Sciences of the U.S.S.R., Moscow, U.S.S.R.

Dr. *J. G. J. Scholte,* V. Alphenstraat 12, Utrecht, The Netherlands.

Dr. *E. Tillotson,* 3, Bleach Mill Lane, Menston-in-Wharfedale, Yorkshire, England.

Prof. *M. Toperczer,* Leiter der Geophysikalischen Abteilung an der Zentralstation für Meteorologie und Geodynamik, Hohe Warte 38, Wien XIX, Austria.

Mr. *E. Tryggvason,* Vedurstofan, Reykjavik, Iceland.

Dr. *E. Vesanen,* Seismological Station, Siltavuorenpenger 20, Helsinki, Finland.

Prof. *V. Vukojičić,* Directeur de l'Institut Séismologique, Beograd, Yougoslavie.

Prof. *A. Zátopek,* Institute of Geophysics, Charles University, Ke Karlovu 3, Praha II, Czechoslovakia.

GENERAL ASSEMBLY AT TORONTO

(September 3-14, 1957)

TIME-TABLE FOR THE SESSIONS

TUESDAY, SEPTEMBER 3

10.00 a.m. :	Formal Opening and First Plenary Session of the I.U.G.G.
03.45 p.m.:	Association of Seismology and Physics of the Earth's Interior : Professor Bullen gives his presidential address.

WEDNESDAY, SEPTEMBER 4

09.00 a.m. :	First Session : Necrologies of deceased seismologists ; Reports of the Secretary General and of the President of the Committee for the I.S.S.; discussions of these reports.
02.00 p.m.:	Second Session : Discussion on reorganisation of the Association of Volcanology and its relations to the Association of Seismology and Physics of the Earth's Interior ; the place of radioactivity within I.U.G.G.

THURSDAY, SEPTEMBER 5

09.00 a.m. :	Third Session : Scientific communications : Magnitude and earthquake energy.

FRIDAY, SEPTEMBER 6

09.00 a.m.:	Fourth Session : Scientific communications : Crustal structure of continents and ocean basins.
02.00 p.m.:	Fifth Session : Scientific communications : Travel times, velocities, and internal structure.

SATURDAY, SEPTEMBER 7

09.00 a.m. :	Sixth Session : Scientific communications : Crustal structure of continents and ocean basins (cont.).
02.00 p.m.:	Extra session concerning recording of an announced nuclear explosion in Nevada.

MONDAY, SEPTEMBER 9

09.00 a.m. :	Seventh Session (together with the Association of Volcanology) : Scientific communications : Physico-chemical interpretation of the terms magma, crust, and substratum.
09.00 a.m. :	Eighth Session : Scientific communications : Instruments and Microseisms.

02.00 p.m.: Ninth Session (together with the Association of Volcanology): Scientific communications: Geochronology and Radioactivity.

02.00 p.m.: Tenth Session : Scientific communications : Seismological geography.

TUESDAY, SEPTEMBER 10

09.00 a.m. : Eleventh Session (together with the Association of Volcanology): Scientific communications: Geochronology and Radioactivity (cont.).

09.00 a.m. : Twelfth Session : Scientific communications: Constitution of the Earth.

01.45 p.m.: Thirteenth Session (together with the Association of Geodesy): Scientific communications: Gravity anomalies and Isostasy.

WEDNESDAY, SEPTEMBER 11

09.00 a.m. : Fourteenth Session (together with the Association of Volcanology): Scientific communications : Geochronology and Radioactivity (cont.).

09.00 a.m.: Fifteenth Session : Scientific communications : Seismic waves.

02.00 p.m.: Meeting of the European Seismological Commission.

02.00 p.m.: Sixteenth Session (together with the Association of Volcanology): Scientific communications : Geothermy and Tectonophysics.

THURSDAY, SEPTEMBER 12

09.00 a.m.: Seventeenth Session : Scientific communications : On the fault plane work.

01.45 p.m.: Meeting of the Committee of the International Seismological Summary.

01.45 p.m.: Eighteenth Session (together with the Association of Geodesy): Scientific communications: Gravity anomalies ; Isostasy.

04.00 p.m.: Nineteenth Session (together with the Association of Volcanology): Scientific communications: Tectonophysics (cont.).

FRIDAY, SEPTEMBER 13

09.00 a.m.: Twentieth Session : Scientific communications : Seismic waves (cont.).

11.00 a.m.: Meeting of the Committee of the International Geophysical Year.

03.00 p.m.: Twenty-first Session: Election of Bureau, Executive Committee, and the Committee for the Physics of the Earth's Interior; report of the Finance Committee; discussion of resolutions; report on Seismological Dictionary. Closing of the Assembly of the Association.

SATURDAY, SEPTEMBER 14

10.00 a.m.: Formal Closing and Second Plenary Session of the I.U.G.G.

LISTE DES PARTICIPANTS AUX SÉANCES DE L'ASSOCIATION

(3 au 14 septembre 1957)

(Liste établie d'après les signatures portées sur les feuilles de présence et complétée autant que possible)

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

Séance	1	4 septembre matin
	2	4 septembre après-midi
	3	5 septembre matin
	4	6 septembre matin
	5	6 septembre après-midi
	6	7 septembre matin
	7	9 septembre matin (Etude du magma)
	8	9 septembre matin (Appareillages, Microséismes)
	9	9 septembre après-midi (Géochronologie)
	10	9 septembre après-midi (Géographie séismologique)
	11	10 septembre matin (Géochronologie)
	12	10 septembre matin (Constitution de la Terre)
	13	10 septembre après-midi (Isostasie)
	14	11 septembre matin (Géochronologie)
	15	11 septembre matin (Ondes séismiques)
	16	11 septembre après-midi (Géothermie - Tectonophysique)
	17	12 septembre matin (Fault Plane Work)
	18	12 septembre après-midi (Anomalies gravimétriques)
	19	12 septembre après-midi (Tectonophysique)
	20	13 septembre matin (Ondes séismiques)
	21	13 septembre après-midi (Assemblée Générale de l'Association)

Il n'a pas été établi des listes de présence pour les séances 14 et 19.

MM.	Abdulla (Soudan) :	3.
	Abelson (U.S.A.) :	3, 4, 6.
	Adams (U.S.A.) :	3, 9.
	Afshar (Iran) :	13.
	Aitken (U.S.A.) :	7, 11, 16, 17.
	Allan (U.K.) :	12, 16, 17, 18, 20.
	d'Arnaud Gerkens (Pays-Bas) :	3, 4, 9, 15, 17, 18.
	Aswathanarayana (Inde) :	9, 11.
	Atkinson (U.K.) :	13, 16, 18.
	Bagliello (Argentine) :	13.

MM.	Baily (U.S.A.):	3, 4, 5, 6, 8, 10, 12, 13, 15, 16. 17, 18.
	Balavadze (U.R.S.S.):	2, 3, 6, 13, 15, 16, 18,
	Bancroft (Canada):	8, 13, 16, 18.
	Baranov (France):	16, 18.
	Båth (Suède):	1, 2, 3, 4, 5, 6, 8, 10, 12, 13, 15, 16, 17, 18, 20, 21.
	Beals (Canada):	16, 17, 18, 20.
	Beck (U.K.):	8, 12, 16, 17, 18.
	Beloussov (U.R.S.S.):	1, 2, 4, 7, 10, 13, 16.
	Benioff (U.S.A.):	1, 2, 3, 4, 5, 8, 10, 12, 15, 17, 18, 20, 21.
	Benson (U.S.A.):	3, 6, 9.
	Betz (Canada):	16.
	Birch (U.S.A.):	4, 5, 6, 7.
	Birkenhauer (U.S.A.):	1, 3.
	Blake (U.S.A.):	3, 5, 9, 13, 16, 17, 18, 20, 21.
	Blanchard (Canada):	3, 4.
	Bogdanov (U.R.S.S.):	1, 3, 4, 6, 8, 13, 17, 18, 20, 21.
	Bomford (U.K.):	13.
	Boukchnikaschwily (U.R.S.S.):	3.
	Bremaecker De (Congo belge):	1, 2, 3, 4, 5, 8, 10, 12, 13, 15, 17, 18, 21.
	Broggi (Pérou):	3, 15, 17.
	Brockamp (Allemagne):	6, 17.
	Brooks (U.S.A.):	8, 12, 15, 17, 20.
	Browne (U.K.):	13.
	Bucher (U.S.A.):	13, 16, 17, 18.
	Bullerwell (U.K.):	13, 18.
	Bruins (Pays-Bas):	13, 16.
	Bullard (U.K.):	6, 12, 16, 21.
	Bullen (Australie):	1, 2, 4, 5, 16, 21.
	Burris (U.S.A.):	13.
	Byerly (U.S.A.):	1, 3, 4, 5, 6, 8, 10, 15, 17, 20.
	Cagniard (France):	6, 7, 11.
	Caloi (Italie):	2, 3, 4, 6, 8, 12, 15, 16, 17, 18, 20, 21.
	Carder (U.S.A.):	1, 2, 3, 4, 6, 8, 10, 15, 16, 17, 21.
	Chambers (Canada):	16.
	Chargoy (Mexique):	15.
	Clark (U.S.A.):	5, 6.
	Clegg (U.K.):	9.
	Clements (U.S.A.):	12.
	Collett (Canada):	13, 17, 18.
	Cook (U.K.):	18.
	Cooper (U.K.):	9.
Mlle	Coron (France):	18.
MM.	Coulomb (France):	2, 4, 8, 10, 13, 17, 18.
	Cox (U.S.A.):	6, 7, 13 15, 16, 17, 18.
	Creer (U.K.):	9, 16.
	Cresswell (U.S.A.):	10.

MM.	Gorshkov (U.R.S.S.):	7, 16.
	Gottfried (U.S.A.):	9, 11.
	Goubin (U.R.S.S.):	2, 4, 10, 12, 21.
	Graf (Allemagne):	17.
	Graham (U.S.A.):	7, 9, 15, 16.
	Gray (Canada):	15, 16.
	Green (U.K.):	16.
	Grenet (Alger):	3, 17.
	Grossling (U.S.A.):	4, 5, 8, 12, 13, 15, 16.
	Guérin (France):	6, 8.
	Gutenberg (U.S.A.):	1, 2, 3, 4, 5, 6, 8, 10, 12, 13, 15, 16, 17, 18, 20, 21.
	Hamilton (U.S.A.):	12.
	Hammer (U.S.A.):	13.
	Harding (Canada):	6.
	Harrison:	6.
	Harwood (Canada):	7, 18.
Mme	Hée (France):	1, 2, 4, 6, 7, 9, 11, 16, 17, 18.
MM.	Heezen (U.S.A.):	9, 10, 16.
	Heiskanen (Finlande):	13.
	Hernández (Argentine):	17.
	Heroy, Jr. (U.S.A.):	8, 12.
	Hersey (U.S.A.):	15.
	Hess (U.S.A.):	4, 5, 6, 7, 9, 12, 15.
	Hill (U.K.):	3, 4, 5, 6, 8, 10, 11, 15.
	Hodgson E. A. (Canada)	17.
	Hodgson J. H. (Canada):	1, 2, 3, 4, 8, 10, 12, 15, 16, 17, 21.
	Hood (U.K.) :	9, 16.
	Houtermans (Suisse):	9, 16.
	Howell, Jr. (U.S.A.):	3, 4, 5, 6, 12, 13.
	Hughes (U.K.):	1, 2, 3, 4, 5, 8, 10, 21.
	Hughson (Canada):	3, 13, 16, 18.
	Hurley (U.S.A.):	9.
	Imbo (Italie):	7, 11.
	Ingram (Irlande):	1, 2, 3, 4, 6, 8, 13, 15, 17, 18, 20, 21.
	Iñiguez (Républ. Dominic.):	1, 3, 6, 10.
	Innes (Canada):	13, 16, 18.
	Jackson (Canada):	4.
	Jaeger (Australie):	3, 6, 8, 9, 15, 16, 17, 20.
	Jardetzky (U.S.A.):	3, 6.
	Jarman (U.K.):	8.
	Jeffreys (U.K.):	1, 2, 3, 4, 5, 6, 9, 12, 13, 15, 16, 17, 21.
Mme	Jobert (France):	3, 4, 5, 6, 8, 12, 13, 17, 18, 20.
MM.	Jacobs (Canada):	16.
	Katz (U.S.A.):	3, 4, 5, 6.
	Keilis-Borok (U.R.S.S.):	1, 2, 3, 4, 5, 6, 10, 12, 15, 16, 17, 21.
	King (U.K.):	6, 8, 13, 16.

MM.	Kivioja (U.S.A.):	13.
	Knopoff (U.S.A.):	4, 5, 7, 12, 13, 15, 16, 17, 18, 20, 21.
	Koczy (U.S.A.):	9, 16.
Mme	Kondorskaya (U.R.S.S.):	3, 4, 5, 6, 10, 16, 21.
M.	Kuno (Japon):	7, 9, 11, 16.
Mme	Labrouste (France):	1, 2, 3, 4, 5, 6, 10, 12, 15, 16, 17, 18, 20, 21.
MM.	Laclavère (France):	7.
	Lacoste (U.S.A.):	13.
	Lagrula (France):	13, 16, 18.
	Lambert (U.S.A.):	13.
	Landisman (U.S.A.):	3, 4, 5, 6.
	Lapwood (U.K.):	1, 2, 3. 4, 5, 6, 8, 12, 15, 16, 17, 18, 20, 21.
	Lebeder (U.R.S.S.):	7.
	Lebedinsky (U.R.S.S.):	12.
	Le Comte :	3, 4.
	Leith (U.S.A.):	4, 6, 7, 9.
Mlle	Lehmann (Danemark):	1, 3, 4, 5, 6, 8, 10, 12, 17, 21.
M.	Lomnitz (Chili): :	3, 8, 10, 12, 13, 15, 16.
Mme	Lubimova (U.R.S.S.):	3, 4, 12, 16, 21.
MM.	Luskin (U.S.A.):	3, 4, 6.
	Lynch (U.S.A.):	1, 3.
	MacCarthy (U.S.A.):	3, 4, 5, 6, 8, 10, 12, 16, 17, 18.
	Macdonald (U.S.A.):	7, 9, 11.
	Magnitsky (U.R.S.S.):	2, 4, 5, 6, 12, 16, 18, 21.
	Mair (Canada):	1, 8.
	Maldonado-Koernell (Mex.):	7, 9, 16.
	Manchee (Canada):	3, 4, 12, 13.
	Mandelbaum (U.S.A.):	9, 13, 16, 17.
	Mansfield Adams (U.S.A.):	3, 4, 5, 6, 8, 12, 15, 17, 20.
	Markowitz (U.S.A.):	13.
	Maynes (Canada):	2, 9.
	MacCahan (U.S.A.):	13.
	McIntyre (U.S.A.):	3, 4, 5, 13, 16, 17.
	Meisser (Allemagne):	1, 2, 3, 4, 5, 6, 8, 10, 12, 13, 15, 17, 18, 20, 21.
	Melchior (Belgique):	13.
	Mescherikov (U.R.S.S.):	4, 12, 13, 16, 18.
	Message (U.K.):	9, 10.
	Migaux (France):	2, 6, 9, 12, 13, 15, 16, 18.
	Miller (U.S.A.):	13, 16.
	Mirynesh (Canada):	3, 4, 16.
	Misener (Canada):	1, 5, 16.
	Miyake (Japon):	9.
	Monges Lopez (Mexique):	6.
	Mooney (U.S.A.):	4, 5, 8, 9, 12, 13.
	Morelli (Italie):	6, 13, 16, 18.
	Morley (Canada):	7.
	Mousuf (Canada):	7, 9, 16.

MM. Murphy (U.S.A.):	1, 2, 3, 4, 6, 17.
Murtay (India):	9.
Naboko (U.R.S.S.):	7, 16.
Nafe (U.S.A.):	4, 5, 8.
Neumann F. (U.S.A.):	3, 4, 6, 10, 13.
Neumann van Padang (Pays-Bas):	7, 11.
Noel (Canada):	3, 4, 6, 8, 9, 12, 15, 16.
Noetzlin (France):	7, 9, 11, 18.
De Noyer (U.S.A):	3, 4, 5.
Nurmia (Finlande):	9, 11.
Nuttli (U.S.A.):	1, 2, 3, 4, 5, 6, 8, 10, 12, 13, 15, 16, 17, 18.
O'Brien (U.K.):	3 4, 6, 8, 12, 13, 15, 16, 17, 20.
Olczak (Pologne):	6, 8.
Oldham (U.S.A.):	6, 13, 16, 17, 18.
Oliver H. W. (U.S.A.):	4, 5, 13, 18.
Oliver J. (U.S.A.):	1, 2, 3, 4, 5, 6, 8, 12, 13, 15, 16, 17, 20.
Orlin (U.S.A.):	13.
Ozima (Japon):	4, 7, 9, 11.
Pekeris (Israël):	1, 4, 5, 6, 12, 15, 16.
Penta (Italie):	7.
Peoples Jr. (U.S.A.):	5, 13, 15, 17.
Pepper (U.S.A.):	13.
Peterschmitt ((France):	1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 13, 15, 16, 17, 20, 21.
Petrie (U.S.A.):	5.
Phemister (U.K.):	7, 9, 11.
Piip (U.R.S.S.):	7.
Pincus (U.S.A.):	7, 9, 12, 13, 15.
Podre (U.S.A.):	9.
Poire (U.S.A.):	7.
Pooley (U.S.A.):	3, 5, 6, 8, 9, 13, 15, 16, 17, 18.
Popov (U.R.S.S.):	3, 6, 8, 10, 15, 21.
Press (U.S.A.):	1, 2, 3, 4. 5, 6, 8, 12, 13, 15, 16, 17, 18, 20, 21.
Ratcliffe (Canada):	18.
Reichenecker (Allemagne):	13.
Reinhardt (Canada):	16.
Revelle (U.S.A.):	16.
Rice (U.S.A.):	13.
Richards (Canada):	3, 4, 6, 7, 8, 13, 15, 16, 17.
Richter (U.S.A.):	1, 2, 3, 4, 5, 6, 8, 10, 12, 15, 16, 17, 21.
Ringwood (Australie):	5, 6, 9.
Rittmann (Egypte):	7, 16.
Riznichenko (U.R.S.S.):	1, 3, 4, 8, 10, 12, 13, 15, 17, 20, 21.
Robertson (U.S.A.):	4, 6, 13, 15, 16, 17.

GENERAL ASSEMBLY AT TORONTO

(September 3-14, 1957)

PROCEEDINGS OF THE SESSIONS

TUESDAY, SEPTEMBER 3

Presidential address

The session is opened at 3.45 p.m. In the presence of a large audience *President Bullen* gives his presidential address on « Seismology in our Atomic Age » to the Association of Seismology and Physics of the Earth's Interior. The complete text of the presidential address is given in the following pages.

The session is closed at 4.45 p.m.

SEISMOLOGY IN OUR ATOMIC AGE

by K. E. BULLEN.

(Presidential Address to the International Association of Seismology and the Physics of the Interior of the Earth, Toronto, September 3, 1957)

It seems to me that this year 1957 is for two reasons a most unusually interesting time for our Association to be meeting, and I feel a little awed that it should fall to my lot to address you at this time.

The first reason is that our meeting is taking place inside the International Geophysical Year, so that many of our activities will be contributing directly or indirectly to an event in the history of Science which has drawn attention to Geophysics as never before.

The second reason, not quite so specific to the year 1957, though highly relevant to the present time, is that the evolution of nuclear knowledge has now reached the point where it offers the possibility of revolutionary new attacks on important problems in seismology and the physics of the interior of the Earth.

The present time is not only intensely interesting to seismologists, but it is also extremely tantalising. We are witnessing many of our fellow geophysicists, especially those concerned with the upper atmosphere, using rockets and other methods of direct observation to extend their knowledge in quite new ways in this International Geophysical Year. And we most positively wish them well. Radically new elements of control are entering their experiments and are steadily supplanting many older less controlled methods of attack.

In seismology, where the release of energy at a natural earthquake focus is unseen and uncontrolled, we battle hard to reduce uncertainties in our inferences from the data Nature provides us with. In studies of the Earth's outer layers, we have contrived some experimental control at source by using limited artifical explosions to complement and supplement our findings from natural earthquakes. Since 1945, we have glimpsed the possibility of extending this control to the point where waves of seismic type can be sent artificially to the very deep interior and be recorded at the surface to tell their tale. But as yet the new skills are hardly available to us.

In these circumstances, I have had the temerity to select for my address the ambitious title of « Seismology in our Atomic Age ». I shall first try to take stock of some achievements prior to the dawn of this atomic age, and then in the later part of my address go on to discuss the impact of atomic explosions on our search for knowledge of the Earth's interior.

In first touching on some of the history of our subject, I have of necessity to be selective, both because of the limitations on what can be said in one hour, and also because it is prudent for me to say most about those parts of seismology that I happen to know best. Thus I hope that those among you who are expert in branches that I may refer to at best only very casually will understand that my selection is not intended to imply any estimate of the relative importances of the different branches of our many-sided subject.

The history of earthquake study as I see it can be divided very roughly into five periods.

From the nebulous past up to about 1750 A.D. runs the first period during which Nature herself was the principal actor on the scene. There were plenty of earthquakes, but apart from a few isolated efforts, such a Choko's in China, the long reluctance to regard earthquakes as natural phenomena forbade activity beyond the haphazard recording of some of the more disastrous shocks.

During the last two centuries, Nature has continued to provide us with earthquakes and we on our part have developed an important science. The second period, which includes John Michell's famous memoir, runs from about 1750 to 1850. It covers the early empirical stage with the amassing of much qualitative data — the appraisal of geological effects of earthquakes and of effects on buildings and the publication of earthquake lists and catalogues.

This was a necessary prelude to the virile third period occupying roughly the latter half of the nineteenth century — a transition period during which seismology began to emerge as a real quantitative science using physical apparatus and mathematical methods.

The third period opened with Mallet's proposal to have a world-wide system of observatories, and saw the development of great schools in Britain, France, Germany, Italy, Japan, Russia, Switzerland. It saw the construction of Milne's seismograph and the actual realisation of efficient observatories on a world-wide basis. And it culminated with Oldham's identification of P, S and surface waves on seismograms, and Wiechert's suggested use of seismology to test the presence of a central core in the Earth. By the end of the period, the foundations of mathematical seismology had also been laid in work of Cauchy, Poisson, Stokes, Green, Kirchhoff, Kelvin, Rayleigh and others.

Then came a fourth period which I think can be discerned as running through the present century to about the start of World War II. This was the fruitful period in which the foundations already laid were applied to unravel the broad structure of the Earth's interior to a degree which must be regarded as remarkable even in this remarkable twentieth century. Nowadays when, for example, we debate the extent to which the P velocity may increase or decrease with depth in various parts of the Earth, we rather tend to take very much for granted the achievements of that great fourth period which started with the vaguest notions about the existence of a molten central core, and finished with well-determined values of compressibility-density and rigidity-density ratios throughout much of the Earth.

On near earthquakes, there was the early work in Europe of Mohorovičić, Conrad, Jeffreys, Gutenberg and subsequently of many others in many regions, building up evidence on subcontinental structure. There was the complementary work of Lamb, Love, Jeffreys, Stoneley, Sezawa, Kanai and others on seismic surface waves, which provided important equations of condition on the allowable structures. There was the revelation in work of Tams, Angenheister, Stoneley, J. T. Wilson and others, of marked differences between continental and oceanic structures. And there was the work of Knott, Jeffreys and later Cagniard on reflection and refraction.

There was Oldham's positive detection in 1906 of the central core. There were the accomplishments of Wiechert's school in Göttingen, for example Zöppritz's early travel-time tables and Gutenberg's calculation in 1913 of the depth of the core boundary. There was the work of Herglotz, Bateman, Wiechert and Slichter on the integral equation which enabled the P and S velocities to be readily computed from the travel-time data.

There was the rise of the International Seismological Summary, under Turner of Oxford, and of the Central Bureau at Strasbourg under Dr. E. Rothé, the distinguished father of the present distinguished Director, Professor J.-P. Rothé. There was the rise of the Jesuit Seismological Association, the passing of whose leader Dr. Macelwane we lament today, and of the seismological division of the United States Coast and Geodetic Survey — organisations which have all contributed so notably to the global study of earthquakes.

The fourth period saw the evolution of travel-time tables from the crudest beginnings, through the Zöppritz-Turner tables to the tables of today in which errors for many phases are reduced to a few seconds or less. This was the period in which the producers of the I.S.S., and Gutenberg and Richter, and others, revealed the principal characteristics of the Earth's seismicity. It was the period in which the problem of the existence of deep-focus earthquakes was settled by the work of Wadati, Stechschulte, Scrase, Jeffreys and Stoneley. There was Miss Lehmann's interpretation in 1936 of the time-curve branch now known as PKIKP in terms of an inner core, supported in 1938 by Gutenberg and Richter's check on the relevant travel-time data, and in 1939 by Jeffreys' use of Airy's theory of diffraction near a caustic to show that the competing hypothesis of diffraction was untenable.

By the end of the fourth period, the travel-time tables had reached the precision where the interior of the Earth could be charted out broadly into several distinct layers. The precision was such that Jeffreys was able to show, for example, that the Earth's ellipticity of figure could now be computed from seismic data alone, within an uncertainty of order one-sixth.

It was my great privilege to enter seismology during the last decade of the fourth period as a pupil of Jeffreys at a time when he had begun his comprehensive revision of travel-times ; and I had the fortune of collaborating with him in this work over the years 1932 to 1940. It was this work that led me in 1940 and 1942 to introduce the notation A, B, C, D, E, F, and G for the broad internal layering of the Earth, with the division of D into D' and D" made in 1949. A little later, I shall comment on the uncertainties in the velocity variations in some of these layers.

It is of central importance to my purpose today that I should stress how hard-won was the knowledge gained in the fourth period. The feature that made the construction of reliable travel-time tables difficult was not primarily shortage of data, but, on the other hand, the problem of treating vast quantities of data which were confounded by troublesome uncertainties at source.

Looked at in the simplest light, the problem was one of least-squares. Suppose that m natural earthquakes are used to form a travel-time curve. Then each earthquake being uncontrolled, there is at the outset ignorance of $4m$ parameters which specify the latitude, longitude, depth and origin-time of each earthquake source, even when treated simply as an impulsive point source. In addition, there are the parameters, say p in number, needed to specify the table to appropriate precision. These $4m + p$ unknowns are subject to mn equations of condition where n is the average number of seismograms used per earthquake. In practice, m, n and p need to be roughly of the order of 100 to lead to results of reasonable precision. So the problem resembled that of finding some 500 unknowns subject to some 10,000 equations of condition ; and this was in the days before giant computing machines were available.

But even this picture is deceptively simple, for the errors in recording the onset-times of seismic phases are by no means normally distributed. They arise from a multiplicity of causes — personal errors in reading, the difficulty of identifying emersio and sometimes even impetus readings against disturbed backgrounds, the influences of unknown geological structures, the actual complexity of conditions at an earthquake source, — uncertainties on the degree of spread of the focal region, on the spread in time of the principal issue of energy from the focus, the possible complication of multiple earthquakes, and uncertainty on the degree to which P and S waves can be assumed to leave the focus together.

In such a setting, the principles of scientific inference demand that statistical considerations shall be prominent, in conjunction with the relevant wave and elasticity theory. The basis of the needed methods was supplied by Jeffreys, and I had the unique experience of observing at close first-hand the sheer genius with which he weaved his way through great masses of numerical data. Deeply ingrained in his methods is the notion of probability — a probability which relates both to the conclusion arrived at and to the evidence on hand at the time — a probability whose value can thus change as new evidence emerges.

The J.—B. tables aimed to produce the most probable travel times that could be inferred from the available I.S.S. data. They apply to a spherically symmetrical model Earth defined so that each internal surface of constant P and S velocity encloses the same volume as the corresponding surface in the actual Earth. The tables thus correspond in a sense to an 'average' earthquake, and do not allow for surface regional variations apart from ellipticity effects.

It has not always been adequately appreciated that the data used, massive though it was, and supplemented by special studies, had limitations in what might be called the 'resolving power'. Just as an optical instrument has its resolving power, so there are limits to the precision to which a given set of natural earthquake data can resolve the internal structure of Earth.

A case in point is the 20° discontinuity, first noticed by Byerly and later more widely observed in the course of the J.—B. analysis. There is first the uncertainty in the precise location of the bend on the travel-time curve, and then there is the accentuated uncertainty in the location of the depth at which the corresponding velocity changes set in. In 1939, the depth was placed by Jeffreys near 400 km. The cautions innate in his papers should not be overlooked : his discrimination for example in favour of discontinuities in the velocity gradients rather than in the velocities themselves was made only after a fine consideration of a slender balance of probabilities. Miss Lehmann's recent work (1) has shown the compatibility of present data with the occurrence of abrupt velocity changes at a depth as little as 200 km. At the other extreme, Gutenberg finds compatibility with fairly steep curves running smoothly down to 1.000 km, with sharp reductions in gradient near this depth. The various results are indicative of the large uncertainties, at present unresolvable, in currently assigned velocity gradients in the regions B and C.

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(1) Lehmann, I., The velocity of P and S waves in the upper part of the Earth's mantle, Bureau Centr. Séism. Internat., Série A, Fasc. 19, 115-123, 1954.

It is part of the method of Jeffreys that a smooth curve through a set of observational points is to be preferred to a jagged one, unless there is significant evidence to the contrary. This does not mean that the smoothed curve is the reality, nor that the curve should necessarily stay smooth when new data appear. It may in fact well happen that an important physical reality is concealed by a smoothing process justifiably carried out on the data on hand at the time. It is part of a sound scientific method that one refrains from introducing an additional parameter in describing a set of observations until the evidence positively warrants it. In this and other matters, an all-important feature of the methods of Jeffreys is that they follow a uniform procedure. His work indicates where he stands on probability, so far as can be in the highly complex problem of the Earth's structure.

Thus in the region B, where Gutenberg has put forward his strong evidence for diminution of velocity with depth, Jeffreys has postulated a diminution just compatible with the condition $dv/dr \leqslant v/r$. A model which satisfies this criterion avoids premature trouble with unpleasant mathematical singularities, and can give useful service so long as it fits the data with reasonable probability.

Another part of the Earth where uncertainties loom large is the region F, that 100 km-thick region of negative velocity gradient which, on balance of probability, Jeffreys finds to lie between the inner and outer parts of the core. It is, incidentally, well to remember that the P velocity distribution set down for F was postulated by Jeffreys — not deduced — and is only one of many possible distributions compatible with the data. But the method of Jeffreys is again clear in that he postulates the simplest law compatible with his data. Gutenberg has constructed a somewhat different model which does not reveal a region F of negative velocity gradient, but he has stated that his data are not yet sufficient to refute the existence of the region F.

The procedures of Jeffreys are important to my purpose today because they indicate well both the strength and limitations of our natural earthquake data. In particular, they show the limitations of the resolving power in those parts of the Earth where there are abnormal variations of velocity.

At the same time, I should not wish it to be thought that I underestimate the great contributions of a host of other seismologists in this important field of travel-time tables ; to name but a few — Lehmann, Byerly, Macelwane, Brunner, and especially Gutenberg and Richter. The close agreement on so many points between the Gutenberg-Richter tables and J.-B. tables is in fact evidence of the general reliability of the velocity values derived, especially in the regions D', E and G. The uncertainties in the derived velocity gradients, vexations as they are, should not distract attention from the fact that the Jeffreys and Gutenberg P and S velocity values have led to values of k/ρ and μ/ρ (k = incompressibility, μ = rigidity, ρ = density), mostly correct to a few per cent. It was through the quality of these results that I was led to construct my Earth Model A giving values of the density, pressure, elasticity and gravity variation in the Earth. Our present picture of the Earth's broad layering derives from these P and S velocity values. What we need now is the further detail which can come only from better knowledge of the velocity gradients.

There were many other achievements in that fourth period, some of them incidentally crucial to the work on travel-times. There were the great instrumental developments of Omori, Wiechert, Galitzin and Benioff, to select again but a few of the outstanding names, and the consequent furnishing of finer information on the amplitudes, periods and general form of the ground movement during an earthquake. There was the work of men such as Adams, Williamson, Bridgman and Birch in geophysical laboratories at Washington and Harvard. There were the early attacks of Nakano, Byerly, Kawasumi, Matuzawa, Tsuboi and others on the problem of movements at the earthquake focus ; of Galitzin, Jeffreys, Gutenberg and Richter on earthquake energy. And this is of course far from being an exhaustive list, either in names or in subject-matter.

I must now hasten on to what I will call the fifth period, running from World War II to the present time. One has only to look at the wide range of interesting titles in our Toronto programme to know how alive seismology is just now. In this fifth period, we have seen not only a continuation of the work of the distinguished schools of the fourth period, but we have also seen large new schools rise from zero to considerable eminence. We have seen the third edition of 'The Earth' by Jeffreys, the second edition of 'The Internal Constitution of the Earth' edited by Gutenberg, and two editions of the 'Seismicity of the Earth' by Gutenberg and Richter. There has been the new attack by the Lamont school on surface wave problems, throwing light on the seismogram coda among other things, and summarised in the recent important book of Ewing, Jardetzky and Press. There are the important advances made by the Russian school, summarised in the book by Savarensky and Kirnos. And, among other noteworthy books. I should mention Cagniard's, which though published about the end of the fourth period, did not become widely known till after the war.

The fifth period has seen the work of Takeuchi and Molodenski on the degree of rigidity in the outer core ; the studies of Jeffreys on the Earth's nutation ; the work of Lapwood and Newlands on surface wave problems ; Birch's notable survey of 1952 on the problems of the interior of the Earth ; the measurements of Bullard, Maxwell, Revelle and others on heat flow in oceanic regions ; the work of Verhoogen, Simon, Jacobs, Uffen and Lubimova on temperature in the deep interior ; and of Hodgson. Ritsema, Koning, Honda, and Keilis-Borok on faulting at the earthquake focus. There have been the work of Hess and Magnitsky on mantle composition, Ramsey's theory of the transition at the core boundary, Urey's powerful use of arguments from physical chemistry, and the work of Elsasser, Knopoff and others involving considerations of theoretical physics. And these again are merely examples, neither wholly representative nor exhaustive, of the activity of the present vigorous fifth period.

Yet, in spite of many undoubted gains in factual knowledge of the Earth in this period, the period is perhaps most notable for the new methods that have emerged or are emerging, and is perhaps best described as another transition period, bearing some analogy to the new growth which took place in the latter half of the nineteenth century.

We have amassed greatly increased numerical data, our seismographs are becoming more and more refined and are giving an ever-increasing coverage of the seismic spectrum. Our work is being vitalised from findings in theoretical physics and chemistry. And we are rich indeed in ideas. But while the new methods and extensions of old ones have yielded notable tangible gains in some fields, and will soon do so in others, there remain further important fields in which the advances do not compare with those made between 1900 and 1940. In particular, much of the imprecision in Earth models that were then current still remains. Uncertainties in the P and S velocity gradients are not yet resolved, and many of our ideas on the Earth's interior cannot be quantitatively tested. For example, I still cannot say which of my Earth Models A and B is to be preferred.

We have indeed produced a multiplicity of theories on happenings below the Earth's outer layers. We discuss pressure and temperature effects, radioactivity, phase changes, chemical composition, variations in compressibility, rigidity, strength and viscosity, possible mechanisms of solid convection currents, and so on. We have known since before 1940 that the regions B and C are the ones in which lie all intermediate and deep earthquake foci, that they are regions of relevance to thermal contraction and related theories, that they are likely to contain the crucial evidence on the observed sequences of island arc formations, ocean deeps, gravity anomalies and volcanic chains. As Birch (2) has said, the regions B and C may well hold « the key to the problem of what is going on in the Earth's mantle ; when we understand their nature, we shall be well on the way to a grasp of the dynamics of the Earth's interior ».

But we are frustrated from grasping this key, in spite of much new data from natural earthquakes. Whereas before the war the I. S. S. was complete only up to 1934, it is now complete to 1948. We thus have fourteen years of new I. S. S. data of improved quality to work on, and we have as well other data from earthquakes since 1948. Yet, as Miss Lehmann has shown us, our resolving power in the regions B and C is of the same order as it was two decades ago. Our inferences are still clouded by the same old uncertainties, in which ignorance of the times and places of natural earthquake foci are major contributing factors.

Nor do the limitations apply merely to the regions B and C. We have not improved our knowledge of velocity gradients in the lowest 200 km of the region D, where we want to know more about the relation between pressure and compressibility, and about the degree of accumulation of denser matter near the bottom of the mantle. We

(2) Birch, F., The Earth's mantle : elasticity and constitution, Trans. Amer. Geophys. Un., 35, 85, 1954.

know only a little more about diffracted waves at distances beyond 105° which might help us to an understanding of the character of the core boundary. There is the tantalising question of the solidity of the inner core, an inference highly plausible on all evidence to date, but eluding positive detection by present seismic methods. The evidence for the region F remains much as it was in 1942. Moreover, even though our geophysical laboratories have produced invaluable information on properties of certain materials over wide ranges of temperature and pressure, reaching to an equivalent of 300 km depth in the Earth, the results cannot be closely linked with conditions in the Earth so long as the seismic velocity gradients remain as uncertain as they are ; and, incidentally, it is still a long way from 300 km depth to the centre of the Earth.

We have not been so limited in our attacks on the problem of the Earth's outer layering. A significant result of the war has been the enhanced knowledge of the technology of explosions. The explosion method of exploring the Earth had of course been introduced long before 1940, and, as well, accidental explosions such as the Oppau explosion of 1921 September 21 had been turned to seismological advantage. But after the war, the application of explosion methods to the traditional near-earthquake problems became feasible on a much increased scale. The source of the energy in these experiments has so far generally been chemical, and the explosions have ranged from the quite small ones of the exploration geophysicist up to the 4000 tons of TNT involved in the Heligoland explosion of 1947 April 18.

The experiments have already had two notable effects. They have forced revisions of a number of earlier near-earthquake studies, and they have brought about an increased awareness of the limitations of natural earthquake data as a means of determining the Earth's outer layering. Byerly (3) has recently written a pungent review of the course of events. We can still debate warmly the interpretation of apparent onsets on seismograms, and an enormous amount of work remains to be done. But we have, in these controlled explosions, the means to carry our knowledge of the Earth's outer layering to greatly improved precision.

It is evident that this same means could give us the knowledge we need of structure below the outer layers if we could produce large enough explosions. Dr. Willmore tells me, however, that to produce waves corresponding to an earthquake say of magnitude 6 would probably require the use of the equivalent of some 30,000 tons of TNT, suitably tamped. And the prospects of doing this would be far from bright were only chemical energy available.

And that is where the present state of nuclear knowledge becomes of special interest, and where the fifth period shows itself to be transitional in yet another and most notable respect. For this period coincides with the dawn of an atomic age in which sources of explosive energy of the requisite magnitude for all seismological

(3) Byerly, P., Subcontinental structure in the light of seismological evidence, Advances in Geophysics, Academic Press Inc., New York, Vol. III, pp. 105-152, 1956.

purposes have become available. The capacity to simulate large earthquakes sending recordable waves far below the outer layers has now been demonstrated. Already we have glimpsed the possibility of controlled experiments which can give us the increased resolving power that we need so badly in problems of the deeper interior.

We have had even more than a glimpse. Some nuclear explosions have already yielded results of value to seismology, even though the seismological applications to date have come only as the merest incidentals to the central purposes of the explosions. I would like now for a few minutes to survey what has been achieved.

The very first atomic bomb, exploded in New Mexico on 1945 July 16, was seismically recorded. The origin-time at source was however, uncertain by 15 seconds, so that this bomb was not as seismologically useful as it might have been. In fact, the seismic data themselves yield the best estimate of the origin-time as 11 h. 29 m. 21 s., which Gutenberg (4) calculates to be accurate within 2 seconds. The results indicated a P_n velocity that agreed within the limits of error with results from regular seismic data in southern California, and there were indications of some other phases, including S phases, in the outer layers. The data have also been discussed by Leet (5).

On 1946 July 24, an atomic bomb was exploded at Bikini atoll. The United States Office of Naval Research gave the origin-time as 21 h. 34 m. 59.76 s. $\pm$ 0.1 s.; and the location as 11°35' N, 165°30' E. This is the sole nuclear explosion to date, so far as I am aware, for which complete and precise source data have been made generally available. Gutenberg and Richter (6) have published P arrival-times of this explosion, recorded by short-period vertical-component Benioff seismographs at eight stations ranging from distances of 69 to 79 degrees, and state that the amplitudes agree with those from an earthquake of magnitude 5·5. In spite of the small number of readings, the fact that the source data were made known enabled a useful inference to be made. The recorded travel-times gave negative residuals against both the J.-B. and the Gutenberg-Richter tables in every case, the mean residual against the J.-B. tables being —1.8 $\pm$ 0.8 sec. (Bullen, 7). The readings thus showed that, for a surface epicentre in the Central Pacific region, the J.-B. tables (which apply to an 'average' earthquake) need a negative correction. The results are compatible with a structure in the Bikini region in which the P velocities are somewhat higher, depth for depth, than in the average continental crust, and point the same way as evidence from surface waves and other sources. Jeffreys (8) has further discussed the Bikini data in his comparison of Japanese and European travel-times. This 1946 Bikini explosion, meagrely recorded as

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(4) Gutenberg, B., Interpretation of records obtained from the New Mexico atomic bomb test, July 16, 1945, Bull. Seism. Soc. Amer., 4, 327-329, 1946.

(5) Leet, L. D., Earth motion from the atomic bomb test, American Scientist, 34, 198-211, 1946.

(6) Gutenberg, B. and Richter, C. F., Seismic waves from atomic bomb tests, Trans. Amer. Geophys. Un., 27, 776, 1946.

(7) Bullen, K. E., The Bikini bomb and the seismology of the Pacific region, Nature, 161, 62, 1948.

(8) Jeffreys, Sir Harold, The times of P in Japanese and European earthquakes, Monthly Notices Roy. Astron. Soc., Geophys. Suppl., 6, 557-565, 1954.

it was, has thus been of value in seismology, and has given a glimpse of what might be achieved with adequate planning in which many more of the world's seismological observatories could participate.

It was not till 1952, so far as I am aware, that any further publication was made of seismological aspects of atomic explosions. In that year, Gutenberg (9) discussed five Nevada explosions which took place in January-February, 1951. The source data were supplied to Gutenberg, but have not been made generally available. From readings at distances up to 400 km, Gutenberg was able to deduce a P_n velocity of 8.20 km/sec and an outer-layer thickness of 35 to 40 km in the region concerned. As in the New Mexico explosion of 1945, some S phases were also recorded.

In the meantime, an important collection of readings of the hydrogen bomb explosion at Eniwetok Atoll on 1952 October 31 has been gathered by Rothé, who has computed an origin-time of 19 h. 15 m. 00 s. and an epicentral location of 11° 40' N, 162° 12' E for this explosion.

The next occurrence of interest was the release of news about the middle of March 1954 that the United States had exploded a hydrogen bomb near Bikini. Reports from Japanese fishermen indicated that the explosion had occurred shortly before dawn on March 1, local time. This information made it feasible for the Director of the Riverview Observatory in Sydney, Fr. T. N. Burke-Gaffney, to search for waves from the explosion on a sufficiently limited section of his vertical-component short-period seismogram. He found a solitary isolated impulse inside the expected range of time. When, later, the routine bulletin from Brisbane arrived, he again found an isolated entry, and the Riverview and Brisbane readings together sharply indicated a source in the direction of Bikini. As bulletins from other centres arrived, it became clear that waves from the hydrogen bomb had been recorded in regular routine at stations in a number of countries. In many cases, there was unawareness that the readings related to the hydrogen bomb.

During March, April and May of 1954, news was released of three further hydrogen bomb explosions, and readings of all four explosions were gathered from countries as widely spread as Australia, New Zealand, the Philippines, the United States, Pakistan, Greece, Sweden, Germany, Japan, Madagascar, Algeria and South Africa. The readings proved to be seismologically interesting, and Burke-Gaffney and I have analysed them in some detail.

A novel question, outside the scope of pure science, soon arose. Was it ethical for scientists in one nation to publish findings on nuclear explosions carried out for private purposes by another nation ? At a meeting in Paris last year of the Council and Executive of the International Union of Geodesy and Geophysics, I raised the question, and Dr. J. W. Joyce very kindly offered to have it discussed in Washington. Later, when I was returning through Toronto, he informed me by telephone that, so far as the United States was

(9) Gutenberg, B., Waves from blasts recorded in Southern California, Trans. Amer. Geophys. Un., 33, 427-431, 1952.

concerned, there would be no objection, ethical or otherwise, to the publication of conclusions from observations gathered in a regular way. A first paper (10) has now in fact appeared, and two further papers have been prepared.

The key to our analysis of the data was an intriguing feature which showed up in the seconds columns in the assembled readings. The feature was that the arrival-times of the first onsets at any one station agreed remarkably in the numbers of seconds past a whole number of minutes of G.M.T. for each of the four explosions. This gave the important clue that the intervals between successive explosions were close to being whole numbers of minutes.

Guided by this clue, and adopting the epicentre of the 1946 Bikini explosion, we were able to show, using the J.-B. tables and correcting for ellipticity, that the explosions must have taken place at Greenwich mean times near to exact numbers of minutes, in fact to exact multiples of five minutes. We allowed for the minus 1·8 seconds correction implied by the 1946 results, and found the data to be consistent with the following origin-times:

(i) Feb. 28 d. 18 h. 45 m. 0 s.

(ii) Mar. 26 d. 18 h. 30 m. 0 s.

(iii) Apr. 25 d. 18 h. 10 m. 0 s.

(iv) May. 4 d. 18 h. 10 m. 0 s.

If the 1946 explosion can be taken as a guide, these times may well be accurate within the order of 0.2 to 0.3 second.

Should this surmised pattern of the exploding of the bombs prove to be correct, some interesting inferences then follow.

First, there is confirmation of the negative residuals found in the 1946 test.

Secondly, the P travel-times from Bikini to Australia and from Bikini to the United States are indicated as being the same, correct to less than a second.

Thirdly, and most interesting, the readings at Pretoria, Kimberley and Tamanrasset, which have epicentral distances between 137° and 142°, appear to throw important light on PKP waves near the 142° caustic. The first onsets at these stations were up to eleven seconds earlier than expected, a very striking result if our surmised origin-times are correct. The early readings at Pretoria and Kimberley were confirmed for us by Dr. Anton Hales, who also found significant larger movements within one or two seconds of the expected arrival-times. The same applies to the Tamanrasset records which were kindly sent to us by Mlle. Grandjean.

The natural explanation of these results is that the early onsets are associated with diffraction near the PKP caustic at 142°, while the larger later movements belong to the PKIKP travel-time branch. Subject of course to the correctness of our surmised origin-times and location, our analysis thus appears to have revealed authentic obser-

(10) Burke-Gaffney, T. N. and Bullen, K. E., Seismological and related aspects of the 1954 hydrogen bomb explosions, Australian Journ. Physics, 10, 130-136, 1957.

vations of PKP diffracted waves, and at times significantly earlier than the PKIKP times. Thus a small final link in the chain of evidence for the existence of the inner core may have been established, and new evidence provided that the PKIKP waves are indeed unconnected with diffraction.

We have since been examining evidence on the occurrence of these diffracted waves in natural earthquakes. Our investigation is not complete, but so far the uncertainties in epicentres and origin-times have prevented us from drawing any very definite conclusions.

The work has in fact highlighted the cardinal advantage innate in atom and hydrogen bomb explosions, in contrast to natural earthquakes, in making inferences on the Earth's interior. From half a century of natural earthquake records, we cannot yet assess the reality of these diffracted PKP waves as firmly as we appear to be able to do from a single set of hydrogen-bomb explosions. I say 'appear to be able', since we do not yet know whether our surmised origin-times are correct.

Our analysis incidentally proved to be interesting in another direction. Dr. Båth drew our attention to a paper by Yamamoto (11) who used microbarograph recordings at a number of Japanese stations to study the four hydrogen bombs, and estimated the mean velocities of air waves from them as 290, 293, 310, 316 metres/sec, respectively. Yamamoto tentatively suggested a seasonal variation in the velocities, though he was aware of possible errors because of the limited area within which all his stations lay. We found that when our epicentre and origin-times were used, the mean velocities all became within 2 units of 321 metres/sec. There was no suggestion of a seasonal variation, and the velocities moreover agreed closely with the velocities of air waves from the Krakatoa eruption of 1883 August 27 and the fall of the Siberian Meteor of 1908 June 30. Gutenberg (4,9) has also given data on air waves from some of the earlier atom bomb explosions.

None of the atom and hydrogen bomb explosions that I have referred to has in any respect been designed to aid seismological research. Such seismological inferences as have been made have been purely incidental. As I have shown, the inferences have been definitely useful but only to a very limited degree. The explosions to date have been grossly inefficient from the seismological point of view, and it is teasing to find ourselves so near and yet so far from really effective use of the new method — so near and yet so far from gaining that more precise knowledge of the Earth's deep interior which we so badly need.

For this reason, I thought it proper, in the interests of our subject, to explore the possibility of having one or more atom bombs exploded specifically for seismic purposes ; and I think it appropriate that I should relate to you what has transpired.

In 1955, a committee was formed consisting of a number of members who have held office in our Association, and on August the first of that year, on behalf of that group, I wrote to the prin-

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(11) Yamamoto, R., Weather, 10, 321, 1955.

cipal scientific bodies in London, Washington and Moscow, putting forward the proposal that one or more atom bombs be exploded for seismological purposes. A copy of the letter was also sent to the Chairman of the Special Committee for the International Geophysical Year.

The letter has since been published in the I.U.G.G. News-Letter (12), so that I need not here give its contents in full. Essentially, the letter summarised the specific advantages of atom bombs over earthquakes for such purposes as I have been describing today, and went on to propose that up to four atom bombs might be exploded at suitable intervals for seismological purposes, perhaps one in the United States, one in the U.S.S.R., one in the vicinity of Australia, and one in the Pacific region. It was made clear that guidance by appropriate experts would be needed on questions of human welfare.

News of the proposal very quickly, and somewhat prematurely, found its way into the world press. There were a number of immediately favourable reactions. Seismologists in general expressed enthusiasm, and encouragement came from scientists in other fields. But before many months had elapsed, it became clear that the proposal had coincided in time with the fairly sudden growth of world-wide fear as to the effects of artificially produced nuclear radiation on the human race.

Initially it had been hoped that the proposal might become part of the International Geophysical Year programme. Two factors almost immediately made it necessary to refrain from pressing for this. First, some fellow geophysicists in other fields felt that the proposal might reduce public support for their own highly important I.G.Y. plans, and of course it is unthinkable that a seismological project should even remotely react against the progress of others in the great I.G.Y. effort. Secondly, the president of a sister Association stated that the detonation of atom bombs during the I.G.Y. could interfere with certain upper atmosphere observations contemplated during this period.

The relevant question now is therefore how far the proposal may bear fruit after 1958. I have tried in this address to indicate just how important explosions of the contemplated type could be in advancing knowledge of the physics of the Earth. I am aware that there are people, including some scientists, who have the strong view that the proposal should not be merely postponed for the duration of the I.G.Y., but abandoned.

My personal view is that the potential advantages of the proposal are so great, that the proposal is so natural a development of one section of our present methods, that sooner or later experiments of the envisaged type must take place. It is, however, not for me to say whether this should be within a few year, as few decades, or later. What I would like to do, and what I feel I should do, because of the surprising publicity the proposal has had, is to take

(12) Bullen, K. E., Proposal on detonation of atomic bombs for seismological purposes, Bull. d'information de l'U.G.G.I., 12, 550-552, 1955.

this opportunity of stating as objectively as I can the attitude of the seismologist to it.

First and foremost, I need to emphasise as strongly as I can that all seismologists I have discussed the matter with, appreciate and accept without reservation, that any plans for atomic explosions that may be instigated at their suggestion must be subject to total scrutiny on the score of human welfare. We recognise that there must be consideration of such matters as the degree of increase in the radioactive content of the atmosphere, sea and land, of possible genetical and other biological consequences, and of suitable times and places and types of contemplated explosions. In view of some public statements that have appeared, it is well that I should state unequivocally that no seismologist would press for an atomic explosion in any circumstances that jeopardised human welfare.

But the issues are not quite scientifically simple. The seismologist has to accept the further fact that public uneasiness on nuclear explosions has now reached a considerable pitch. It is evident that that most primitive of all fears, fear of the unknown, has come powerfully upon many men, especially where nuclear radiation is concerned. This fear is thoroughly understandable and is to be appreciated as a comforting assurance of mankind's deeply ingrained instinct for self-preservation. It is far better that the conceivable risks should be overstated than that they should be understated, even if this should entail some departure from a sense of scientific values and objectivity. Recognising this, seismologists have no wish to push the atom-bomb proposal against the present strong public feeling.

At the same time, it is desirable to keep a sense of proportion. First, it is necessary to recall that the proposal as put forward has related specifically to atom — not hydrogen — bombs. A simple calculation indicates that the proposal would add only an extremely small fraction to the total radioactivity from other artificial sources to date. Secondly, since we are now but at the dawn of the atomic age, the time may well come when the experiments are not only feasible but are found to be thoroughly acceptable on grounds of safety by all responsible people. Perhaps some future holder of this presidential office will find that the proposal can be put into practice without harm, without fear, and with positive benefit to mankind through the new knowledge gained. In the meantime we must be patient, and respectful of world opinion.

There have been other types of criticism of the proposal, which, even though voiced by some scientists, are I think out of perspective. One is that the proposal should be banned for all time on so-called grounds of « morality », since atom bombs, being used for military purposes, are « evil » and « sinister » things. This seems to me a very unscientific use of the word « morality ». On such logic, it would equally follow that because in some countries it may be held immoral to beget a child out of wedlock, it is immoral to beget a child in wedlock. (An attitude which if relentlessy applied would exterminate the race at least as surely as any military activity.)

A related criticism is that the proposed experiments might encourage others to use bombs for purposes not purely scientific. Against this criticism, I put the suggestion that if the leading nations of the world could co-operate in taking advantage of such opportunities as the proposal provides in its small way, this might perhaps be a useful practical step towards merging the use of atomic energy into a real international control, — one step towards ensuring that some rogue nation in the future will not bring real disaster upon mankind.

It is not wise, however, for the seismologist or other scientist to become too far entangled in considerations outside his field. My hope is that objective scientific thought will be brought to bear on the various aspects of the proposal, taking totally into account of course the relevant biological issues.

I come now to the last section of my address in which I am able to report that the proposal has already borne fruit in the form of some governmental co-operation with seismologists in the exploding of bombs intended primarily for non-seismological purposes.

In particular, through the courtesy of British and Australian Government Departments, it has been possible to make and to publish a most valuable study of seismic waves from four atom bombs exploded at Maralinga in Central Australia in 1956. Information given well in advance of the explosions made co-operation possible on a wide scale, and instrumental help came from Great Britain, The United States, Pakistan and South Africa. The stimulus in Britain came from Sir Edward Bullard, and the main field observations were carried out under the direction of Professor J. C. Jaeger of Australian National University at Canberra, with co-operation from the Universities of Sydney and Adelaide.

As a result, we now have the first really reliable knowledge of the P_n velocity anywhere in Australia. For the region running some ten degrees west from Maralinga, the P_n onsets fit a straight line remarkably closely, and tentatively yield a velocity of 8.23 ± 0.02 km/sec. S_n also appears to have been quite well recorded, and with a high velocity tentatively computed as 4.75 ± 0.02 km/sec. There were also phases corresponding to an outer layer in which the P and S velocities are 6.12 and 3.56 km/sec, respectively. There is no evidence of the existence of more than a single layer (apart from sediments) above the Mohorovičić discontinuity. The indicated thickness of the layer is 35 km or a little greater. (The region includes the Nullarbor Plain. The geology of this plain is described as horizontally bedded limestones, known to be 900 feet thick in places, with the Yilgarn pre-Cambrian shield to the west and possibly under the limestones. The three most distant stations were on the Yilgarn shield.)

In Australia, we are, by world standards, very free from earthquakes, and we are also, as yet, well short of having an adequate network of observatories, although during the I.G.Y. the position is being much improved. Thus the 1956 explosions provide one instance in which atom bomb explosions have been turned to great advantage, even though the results relate only to near-surface structure.

Another important series of results on seismic waves generated by nuclear explosions is to be presented later during this meeting by Dr. D.S. Carder of the United States Coast and Geodetic Survey.

Perhaps these results will help those who look upon atom bombs as entirely evil things to appreciate that, in the words of Shakespeare, « There is some soul of goodness in things evil, would men observingly distil out ». Already, seismology is deriving some gains from the atomic age in which we now live.

FIRST SESSION

WEDNESDAY, SEPTEMBER 4 (morning)

Program

1. — Necrologies.
2. — Report of the Secretary General.
3. — Election of a Finance Committee.
4. — Discussion of the report by the Secretary General.
5. — Report of the President of the Committee for the I.S.S.
6. — Discussion on I.S.S. Re-constitution of the I.S.S. Committee.
7. — Discussion concerning re-organisation of I.A.V.

The session is opened at 09.10 a.m. with *Professor Bullen* in the chair.

The president reads messages from several scientists, not being able to attend the assembly :

Prof. *F. A. Vening-Meinesz,* Amersfoort (Pays-Bas).

Dr. *H. Honda,* Geophysical Institute, Tohoku University, Sendai (Japan).

Dr. *K. Wadati,* Japan Meteorological Agency, Tokyo (Japan).

Dr. *H. Jensen,* Geodaetisk Institut, Copenhague (Danemark).

Dr. *E. F. Baxter,* Fieldhouse Terrace, Durham (U.K.).

Dr. *E. Vesanen,* Seismological Station, Helsinki (Finlande).

Dr. *E. Picciotto,* Université Libre de Bruxelles (Belgique).

Prof. Dr. *W. Hiller,* Stuttgart (Allemagne).

Prof. *K. Jung,* Kiel (Allemagne).

Dr. *H. Menzel,* Hamburg (Allemagne).

Dr. *J. M. van Gils, Uccle* (Belgique).

Prof. *A. Zátopek,* Prague (Tchécoslovaquie).

Dr. *N. Pinar,* Ankara (Turquie).

Dr. *E. Lahn,* Ankara (Turquie).

Dr. *H. M. Iyer,* Wormley, Godalming (U.K.).

Dr. *J. Darbyshire,* Wormley, Godalming (U.K.).

Dr. *A. R. Ritsema,* Djakarta (Indonésie).

1. Necrologies

President Bullen pays homage to the scientists of our Association deceased since the last assembly : *J. P. Buwalda, G. Krumbach, J. B. Macelwane, J. B. Marble, J. Mihailović, L. Mintrop, Miss F. Robertson, V. C. Stechschulte, E. Wanner.* The assembly observes one minute of silence to their honour.

President Bullen announces that *Dr. M. Båth* was co-opted as Vice President in place of Dr. Wanner.

John Peter Buwalda (1886-1954) was born December 16, 1886, in Zeeland, Michigan. In 1906 he entered the University of Washington and there, under the inspiration of Charles E. Weaver, received an introduction to geology, which became a lasting dedication. In 1909 Buwalda enrolled as a geology major at the University of California in Berkeley. Upon completion of his doctoral dissertation «A new mammalian fauna from Miocene sediments near Tehachapi Pass on the summit of the southern Sierra Nevada» he received his Ph. D. degree in 1915. Buwalda's major research as a student was in paleontology under the direction of John C. Merriam, his minor was in geology, largely under the direction of Andrew C. Lawson. The influence from these two men was of large significance for Buwalda's further activities. As a result of his Berkeley experience, Buwalda had also come to recognize the necessity for close ties among all the earth sciences and the importance of thorough field training for geologists. In 1915 Buwalda became instructor in physiography at the University of California. After four years (1917-1921) as an assistant professor of geology at Yale University, and in Washington, D. C., for the Geological Survey, he returned as professor of geology (1921-1926) to the University of California. In 1925 he accepted an offer to develop a geological program at the California Institute of Technology and came to Pasadena in 1926. He thereby became the founder of the Division of Geological Sciences, California Institute of Technology, and he was Division chairman from 1926 to 1947, and continued as professor of geology at the institute until his death. He carried a heavy burden of work in administration and in arranging a curriculum suitable to the somewhat specialized needs to the California Institute students, and contributed considerably to the development of his division.

His capacity was much used in connection with geological problems of practical importance. His influence was a primary factor in causing the U.S. Coast and Geodetic Survey to set up a triangulation system across fault lines in southern California to measure the drift on opposite sides of faults. The fundamental work he did on problems on earthquake-resistant structures will long pay dividends to southern California. The titles of his published papers concern the fields of vertebrate paleontology, Cenozoic continental stratigraphy, structure, recent deformation of the earth's crust, earthquakes, seismic explorations, petroleum geology, geomorphology, areal geology, and historical geology. He used physiographic features effectively in investigations of recent movements on active faults, and worked closely with seismologists in studying features created by the fault movements giving rise to notable California earthquakes such as those in Imperial Valley, 1940, and Kern County, 1952. With his colleague Beno Gutenberg he pioneered many phases of the application of seismic exploration to the deciphering of fundamental geological relations.

He was an active member of several scientific societies and was President of the Seismological Society of America, 1951-1953.

He died suddenly on August 19, 1954, while on a field trip.

(This biography is condensed from *Proc. Vol. Geol. Soc. America,* Annual Report for 1955, pp. 107-112, 1956).

Gerhard Krumbach (1895—1955).

Am 23. Dezember 1955 erlag nach langer schwerer Herzkrankheit, die sich im August desselben Jahres auf einer Dienstreise in Bulgarien einstellte, Herr Prof. Dr. Gerhard Krumbach, Direktor des Instituts für Bodendynamik und Erdbebenforschung in Jena der Deutschen Akademie der Wissenschaften zu Berlin, im 61. Lebensjahr einem Herzschlag.

Mit dem Verstorbenen verliert die geophysikalische, wie auch die geologische Fachwelt einen ihrer verdienstvollen Wissenschaftler. Besonders auf dem Gebiet der Seismologie hat Gerhard Krumbach wertvolle Beiträge geliefert. Die von ihm konstruierten Seismographen werden als Stationsinstrumente und zu Sicherheitsmessungen in Bergbaubetrieben verwendet. Es war ihm eine Selbstverständlichkeit, nach dem Kriege beim Wiederaufbau mitzuhelfen. In diesem Bestreben hat er in zahlreichen Fachausschüssen und wissenschaftlichen Kommissionen tatkräftig mitgewirkt. Daneben hat er sich durch seine Lehrtätigkeit an der Friedrich-Schiller-Universität Jena bei der akademischen Jugend ein bleibendes Verdienst erworben. Ferner hielt er es für eine vornehme Pflicht, durch populäre Vorträge breite Volksschichten an seine Wissenschaft heranzuführen und ihr Verständnis für die Forschungstätigkeit zu heben. Als Mitbegründer der Deutschen Geophysikalischen Gesellschaft hat Gerhard Krumbach den Grundstein für eine fruchtbare Zusammenarbeit der deutschen Geophysiker gelegt.

Gerhard Krumbach wurde am 22. März 1895 in Hamburg geboren. Nach erfolgreichem Studium an den Universitäten Freiburg und Göttingen, das er im ersten Weltkrieg längere Zeit unterbrechen musste, erwarb er sich als Assistent bei Geheimrat Wiechert, dem Begründer der instrumentellen Erdbebenforschung, umfangreiche Fachkenntnisse in der allgemeinen Geophysik, vor allem aber in der Seismologie. Ende 1924 wurde er an der neu errichteten Reichsanstalt für Erdbebenforschung in Jena mit dem Arbeitsgebiet «Instrumentelle Seismik» betraut und zum Regierungsrat ernannt. Er promovierte danach bei Wiechert mit einer Dissertation über «Die Laufzeiten von Vorläufern und Wechselwellen in ihrer Beziehung zur Schichtung der Erdrinde». Im November 1945 trat er zunächst als stellvertretender Direktor die Nachfolge August Siebergs an. 1946 wurde er zum Direktor des Zentralinstituts für Erdbebenforschung in Jena ernannt. Zum 25-jährigen Institutsjubiläum 1949 verlieh ihm die Deutsche Akademie der Wissenschaften zu Berlin, der das Institut im Jahre 1947 angeschlossen wurde, den Professortitel. Seiner Umsicht und Tatkraft ist es zu verdanken, dass durch einen Institutsneubau den heutigen Erfordernissen gerecht werdende Arbeitsbedingungen geschaffen wurden. Die Vollendung dieses grosszügigen Bauwerkes mit zu erleben, blieb ihm leider versagt.

(This biography has been kindly supplied by Dr. Fr. Gerecke).

James Bernard Macelwane, S. J., (1883-1956), was born on September 28, 1883, on the northern shore of Sandusky Bay near Port Clinton, Ohio. On August 31, 1903, he joined the Jesuit Order and two years later he took the religious vows as a Jesuit. Except for some years of teaching, he gave his attention to ancient and modern languages, literature, and history, to the natural sciences and mathematics, to philosophy and psychology, and to dogmatic, moral, and ascetical theology. These years of study culminated in ordination to the Catholic priesthood in 1918.

Father Macelwane's early preferences in the matter of specialized study lay in the field of classical languages, and he took his M. A. degree in 1911. He then pursued courses in physics and mathematics, taking an M.S. degree in 1912. He became interested in the theory of the seismograph while at Saint Louis University, and he was coauthor of an article entitled « Physics of the Seismograph », his first technical paper, published in 1911.

After taking the Ph. D. at the University of California in Berkeley in 1923, he stayed there for two more years as an Assistant Professor of Geology. In 1925 he was appointed Professor of Geophysics and Director of the new Department of Geophysics in Saint Louis University, a position he held until his death.

In addition to his research in geophysics which he carried on continuously, he left a deep organizational and scholarly imprint on the University's Graduate School of which he was Dean from 1927 to 1933. In the fall of 1944 he established and was the first Dean of the Institute of Technology, the University's School of Earth Sciences and Engineering. He wrote several books, and 133 technical papers.

Because of his broad and sympathetic interests, his services were in constant demand, both in various national services as well as in over two dozen learned and professional societies. In 1948 he received the William Bowie Medal, and in 1953 he was elected President of the American Geophysical Union. Through his effective leadership the Jesuit Seismological Association was organized in 1925. He was annually elected President of it until his death. The Eastern Section of the Seismological Society of America was also formed in 1925-1926, to which Father Macelwane contributed. One of Father Macelwane's favored diversions from his many labors was to engage in field geology, especially in the foot-hills of the Colorado Rockies.

His death occurred on February 15, 1956.

(This biography is condensed from *Trans. Amer. Geophys. Union,* Vol. 37, No. 2, pp. 135-136, 1956. See also *Earthquake Notes,* Vol. 27, No. 2, 1956, *The Bull. Amer. Assoc. Petroleum Geologists,* Vol. 40, No. 8, pp. 2038-2039, August, 1956, and *Geophysics,* Vol. 22, No. 1, pp. 159-162, January, 1957).

John Putnam Marble (1897-1955) was born May 30, 1897, in Worcester, Massachusetts. He took his Master's Degree in Chemistry at Harvard in 1928 and his doctorate in Analytical Chemistry in 1932 under the guidance of Professor G. P. Baxter.

It was following the receipt of his doctorate that he really began to find his place and great interests as a scientist. He analyzed radioactive minerals first at the laboratory of the U.S. Geological Survey and, since 1935, at the Smithsonian Institution under the auspices of the Committee for the Measurement of Geologic Time of the National Research Council. In this research he worked closely with Professor Alfred C. Lane. These activities continued to occupy a considerable amount of his time until his death. He became Vice Chairman of the Committee in 1936 and, in 1946, shortly before Professor Lane's death, succeeded him as Chairman. The annual reports that he prepared on behalf of the Committee, including as they did extensive critical international bibliographies, are very important contributions to literature in a field that has been growing rapidly in the last few years. His was a work of love, and he devoted long hours to searches of the literature, compiling his bibliography singlehandedly, and preparing his reports, at the same time carrying on his radioactive research work and diverse activities in such organizations as the American Geophysical Union. His other permanent contributions included about twenty scientific papers mostly bearing on geologic-time analyses, published in a variety of journals, including the American Mineralogist, the Journal of the American Chemical Society, and the American Journal of Science.

During World War II he served as Technical Aide and Special Assistant of the National Defense Research Committee of the Office of Scientific Research and Development.

He was an active member of several professional societies.

His other interests included both geological field trips as well as education.

He died on June 6, 1955, in Washington, D.C.

(This biography is condensed from *Trans. Amer. Geophys. Union*, Vol. 36, No. 4, pp. 573-574, 1955. See also *Proc. Vol. Geol. Soc. America*, Annual Report for 1955, pp. 143-146, 1956).

Jelenko Mihailović (1864-1956), director of the Seismological Institute of Belgrade, was born on Jan. 10, 1864 in the village of Vrbitsa (Vrbica), near Zajechar, and died on Oct. 30, 1956 in Belgrade.

He took his degree at the Grand School (later the University of Belgrade) in Belgrade, and then spent some time in Strasbourg, Brussels and Vienna. After he had come back to Belgrade, he lectured on Seismology at the Faculty of Science, and on Meteorology and Climatology at the Faculty of Agriculture and Forestry from 1893 till 1940. He founded, supervised and controlled the work of meteorological stations, administrated the first magnetical observatory, started and organized seismological service in Yugoslavia as well.

He retired in 1939 as the rector of Higher Pedagogical School, but remained to be the director of the Seismological Institute of Belgrade, that he had founded and had been its director since the first day of its foundation. He was its director until his death.

In the course of his many years' activity and rich work, he devoted himself to the problems of Seismology in the first place, but at the same time he worked on the problems of Geology, Meteorology, Astronomy and Physics. A great number of papers and articles he has left behind reveal his great enthusiasm, an unexhausted energy, and unselfishness in transmitting his knowlegde to others and especially in helping younger generations.

In the field of Seismology he decided in the first place to study and work out seismic characteristics of the entire territory of Yugoslavia and its individual active regions, of which he left a great number of written works. But he did not keep himself only on these problems, but at the same time he studied and worked out the seismic characteristics of the whole Balcan Peninsula, and separately of the surrounding countries as Bulgaria, Roumania and Albania.

In the course of his long life, first for a short time as a teacher of physics in Secondary Schools, then at the Faculty, as one of the founders of the Geological Society and of the Seismological Institute of Belgrade as well, he left a light memory of himself in the country, and his collaboration, personal contacts and his works had brought him the esteem and fame not only in scientific circles of Yugoslavia, but even outside of it.

(This biography has been kindly supplied by Prof. V. Vukojičić, Director of the Seismological Institute of Belgrade).

Ludger Mintrop (1880-1956) was born on July 18, 1880, on the estate Barkhoven near Essen-Werden. He studied at the Bergakademie in Berlin and at the Institute of Technology in Aachen. As an assistant of Professor Hausmann at Aachen he came in contact with geophysics which was of decisive importance for his later activities. He started the seismograph station at Aachen. In 1908 he moved to Professor Wiechert at Göttingen, where he started his experiments with artificial shocks and constructed portable seismographs. As a teacher of mining geodesy at the Bergschule Bochum, he started a seismograph station also at Bochum. His dissertation from 1911 in Göttingen had the title : « Ueber die Ausbreitung der von den Massendrucken einer Grossgasmaschine erzeugten Bodenschwingungen ».

Already in 1917 he received patents for a vibration meter, for a field seismograph, and for a method for calculating the locality of an artificial shock. In 1919 he received a patent for methods of seismic prospecting.

Mintrop was one of the founders of Seismos in Hannover in 1921, the first seismic prospecting company in the world. Prospecting for oil and salt was carried out in several European countries, and in 1923 for the first time in America.

Between 1928 and 1945 Mintrop was Professor of Mining Geodesy (« Markscheidekunde ») and Geophysics at the Institute of Technology and the University of Breslau.

Since 1948 Mintrop has several times stimulated research on the deep structure of the earth's crust, especially under the Alps. He has published nearly fifty papers and has in his lifetime received much appreciation for his pioneer work in seismic prospecting.

He died on January 1, 1956.

(This biography is condensed from *Seismos Echo, Hausmitteilungen,* No. 2, pp. 1-7, Febr. 1956 ; see also *Gerl. Beiträge zur Geo-*

physik, Bd 66, Heft 1, pp. 1-3, 1957, and *Zeitschrift für Geophysik,* Jahrg. 22, Heft 1, p. 58, 1956).

Miss *Florence Robertson* (1909-1954) was born in Paris, Texas, November 11, 1909. She received a B. A. degree with a major in mathematics and a minor in education from the Texas Technological College in Lubbock, Texas, in 1935. The following year she received the M. A. degree from the same institution in physics and mathematics with a geophysical thesis. In the Fall of 1936 she entered the Graduate School of Saint Louis University with a graduate fellowship in geophysics. In 1939 she was appointed to an instructorship in geophysics. She obtained the degree of Doctor of Philosophy in 1945 and was made an assistant professor the same year at Saint Louis University. With the founding of the Institute of Technology in 1944 she had prepared herself to take an active part in the development of the curriculum in geophysical engineering. She was made an associate professor in 1948 and a full professor in 1951.

Doctor Robertson was active in many professional and scientific societies. Her papers were devoted to studies of local earthquakes, seismographs, short-period microseisms and most of them were published in the Bulletin of the Seismological Society of America, Transactions of the American Geophysical Union, and in Publications from Saint Louis University.

She died on November 18, 1954, in Wichita Falls, Texas.

(This biography is condensed from *Earthquake Notes,* Vol. 25, Nos 3-4, pp. 42-43, 1954).

Victor Cyril Stechschulte, S. J., (1893-1955) was born October 2, 1893, at Leipsic, Ohio. On August 9, 1912, he entered the Society of Jesus.

His interests were both in the classics and in science. After the completion of his theological studies, he was sent to the University of California in Berkeley.

In 1928, he began his doctorate studies under Dr. Byerly, specializing in deep-focus earthquakes. His dissertation was « The Japanese Earthquake of March 29, 1928, and the Problem of Depth of Focus ». He received his doctorate in 1932 and immediately took up his work of teaching and seismological research at Xavier University, Cincinnati, where he remained until his death.

During World War II, Father Stechschulte was most active in organizing the program of studies followed in the training of officer candidates at Xavier. The burden of administration plus a full teaching load proved too much for his health and in 1944 he suffered a heart attack while saying Mass. From this he never completely recovered, though he returned to teaching and administration, serving as Chairman of the Department of Mathematics and Physics and Director of the Seismological Observatory.

Father Stechschulte has published a number of seismological papers, several of them dealing with deep-focus earthquakes.

His death occurred on March 3, 1955, caused by a heart attack.

(This biography is condensed from *Earthquake Notes,* Vol. 26, No. 1, p. 3, 1955).

Ernst Wanner (1900-1955) was born on July 22, 1900, in Zürich. In 1923 he received the diploma at the Eidg. Technische Hochschule as teacher of mathematics and physics. In 1925 he got his doctor's degree in mathematics at the same institute with a thesis on groups of linear transformations. In 1928 he came to the Schweiz. Meteorologische Zentralanstalt, where he remained until his death. At this place he was in charge of the seismograph stations in Switzerland and later also of the earth-magnetic variometer station Regensberg. He also worked in the weather service, and later as a vice director of the institute he had to devote a large part of his time to administration.

He showed extensive interests in many sciences dealing with nature. His mathematical education was of great importance for his geophysical studies. He always exhibited great care in formulating his conclusions, recognizing the limitations of human observations.

He devoted intensive studies to the seismic conditions in Switzerland and their connections with the tectonics. For distant earthquakes he installed in the seismograph station of Zürich a 1000 kg vertical seismograph, constructed together with A. Kreis. He made an important statistical investigation of the time distribution of earthquakes and of meteorological phenomena. Together with P. L. Mercanton he studied the magnetic anomaly at Jorat (Lausanne). He is the author of more than 50 scientific papers.

He was Vice President of the Association of Seismology and Physics of the Earth's Interior from 1954 until his death. He represented Switzerland in the European Seismological Commission, and he was President of the Swiss National Committee of the I.U.G.G.

He died suddenly on November 4, 1955, by a heart attack.

(This biography is condensed from a more extensive biography written by Prof. F. Gassmann and published in *Verhandlungen der Schweiz. Naturforschenden Gesellschaft,* Porrentruy, 1955).

In addition, we note the death of Father Deppermann.

Charles E. Deppermann, Jesuit scientist of Manila Observatory, died in Manila on May 8, 1957, at the age of 68. He was born in New York. He took his master's degree from Woodstock College in 1918 and his doctorate from Johns Hopkins University in 1925, and studied subsequently at the University of California and St. Louis University. He devoted most of his adult life to work in the Philippines, beginning his service as Chief of the Seismological Division in the Philippine Weather Bureau in 1926. He became Director in 1946 and his recent years were spent in rebuilding the observatory at Baguio, devoting an increasing amount of his efforts to seismology. He had been a member of the American Geophysical Union since 1934.

(This biography has been copied from *Trans. Amer. Geophys. Union,* Vol. 38, No. 4, p. 597, August, 1957).

2. Report of the Secretary General

The Secretary General, *Professor Rothé,* presents his report :

Mes chers Collègues,

Au cours des trois années qui viennent de s'écouler le Secrétariat de votre Association a continué à remplir sa tâche habituelle : liquidation de l'Assemblée générale de Rome, rédaction et impression du Bulletin mensuel, préparation de l'Assemblée de Toronto.

Vous trouverez dans le dossier qui vous sera remis un résumé des opérations financières effectuées du 1er janvier 1954 au 1er janvier 1957. La liquidation de l'Assemblée de Rome s'est traduite par la rédaction et l'impression du volume des Comptes Rendus que vous avez reçu. Je dois signaler l'aide que m'a apportée dans cette rédaction notre collègue M. De Bremaecker qui avait bien voulu à Rome participer au Secrétariat et qui ensuite a bien voulu relire les notes prises en séance. Par ailleurs un volume contenant certains des mémoires qui avaient été présentés devant l'Assemblée de Rome a été publié et constitue le fascicule 19 des Publications Scientifiques de notre Association. Ces publications ont coûté à notre Association 1.788.878 francs, ce qui représente environ 36 % des dépenses totales de l'Association pour la période 1954-1956.

Le Bulletin mensuel du Bureau international a continué à paraître régulièrement. Le nombre des données reçues à Strasbourg s'est accru notablement au cours des dernières années et le bulletin a pu ainsi devenir de plus en plus complet. Nous recevons de nouveau régulièrement les données des stations séismologiques de l'U.R.S.S. et je tiens à remercier ceux de nos collègues russes qui assurent la préparation d'un bulletin résumé qui est très rapidement envoyé au Bureau central pour y être utilisé.

Le travail est assuré à Strasbourg par M. Marzi qui appartient au Bureau international depuis 1950. Devant l'accumulation des données nous avons dû le faire aider à plusieurs reprises par des assistants auxiliaires qui en particulier préparent les fiches sur lesquelles sont reportées les données principales et qui permettent un classement plus rapide. Ce Bulletin a continué à être imprimé sur la Machine Vari-Typer de l'Université de Strasbourg. La préparation des stencils et le tirage sont assurés bénévolement par le personnel de l'Institut de Physique du Globe de Strasbourg.

Le tableau suivant contient quelques données statistiques concernant ce bulletin. Des épicentres aussi nombreux que possible sont indiqués ; bien souvent d'ailleurs 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. Nous portons donc spécialement notre effort sur les séismes pour lesquels la détermination provisoire de l'épicentre peut être précisée (séismes européens, méditerranéens, asiatiques, par exemple) soit parce que nous disposons d'un grand nombre de données d'observatoires soit parce que les observations macroséismiques permettent avec sûreté de fixer l'épicentre. Au moment où je vous parle le bulletin de mars 1957 est en voie d'achèvement, bulletin qui sera extrêmement chargé comme le savent ceux de nos collègues qui

TABLEAU

Mois de	Pages	Nombre de séismes étudiés	Nombre d'épicentres indiqués (coordonnées)	Nombre de régions épicentrales indiquées	Séismes indéterminés
1954					
Janvier	42	125	84	30	11
Février	68	161	109	37	15
Mars	62	156	96	37	23
Avril	54	139	109	21	9
Mai	72	212	139	55	18
Juin	50	151	101	36	14
Juillet	67	175	119	39	17
Août	66	183	137	33	13
Septembre	63	162	117	38	7
Octobre	56	154	105	31	18
Novembre	56	151	99	45	7
Décembre	62	150	107	26	17
	718	1919	1322	428	169
1955					
Janvier	64	157	124	30	3
Février	56	148	99	40	9
Mars	74	180	133	37	10
Avril	74	157	105	46	6
Mai	77	166	115	41	10
Juin	76	173	130	30	13
Juillet	76	167	109	45	13
Août	53	148	83	55	10
Septembre	76	146	92	40	14
Octobre	59	144	95	33	16
Novembre	56	139	92	31	16
Décembre	46	146	88	43	15
	787	1871	1265	471	135
1956					
Janvier	88	214	163	40	11
Février	82	180	141	33	6
Mars	71	186	131	43	12
Avril	56	135	94	31	10
Mai	66	143	109	28	6
Juin	71	145	119	22	4
Juillet	96	176	137	22	17
Août	70	141	112	21	8
Septembre	66	157	102	30	25
Octobre	83	233	126	50	57
Novembre	79	176	114	39	23
Décembre	68	150	114	26	10
	896	2036	1462	385	189

dirigent des stations. Nous avons donc environ 6 mois de retard ; il serait désirable qu'avec une aide accrue nous puissions ramener ce retard à 4 mois environ.

Par ailleurs et conformément au vœu formulé à Stuttgart en 1952 par la Commission Séismologique Européenne nous avons continué à effectuer des déterminations rapides d'épicentres pour les séismes originaires d'une zone située à moins de 5000 km du centre de l'Europe: 21 déterminations ont été faites en 1954; 24 en 1955, 24 encore en 1956. Bien entendu et comme je l'ai déjà dit ces déterminations résultent des données que nous font parvenir rapidement nos collègues européens ou d'Afrique du Nord que je remercie bien vivement de leur collaboration, collaboration indispensable dans le travail séismologique.

Le travail effectué pour préparer le Bulletin mensuel du Bureau international est considéré désormais comme l'un des Services permanents groupés dans la Fédération des Services permanents mise sur pied grâce aux efforts du Secrétaire général de l'Union, M. Laclavère. C'est par l'intermédiaire de cet organisme que sont reçues les subventions de l'U.N.E.S.C.O. qui permettent de faire vivre ces Services permanents.

En ce qui concerne notre Bulletin nous avons reçu de l'U.N.E.S.C.O. pour la période 1954-1956 une subvention totale de 2.196.220 francs soit en moyenne 730.000 francs par an. Pour la même période les dépenses se sont élevées à 3.247.831 francs soit en moyenne un peu plus de 1.000.000 par an. La différence entre ces deux sommes constitue l'un des postes de dépenses de notre Association soit 1.051.611 francs (20 % des dépenses totales).

L'International Seismological Summary constitue l'un des autres Services permanents intégrés dans la Fédération des Services permanents de l'Union. L'I.S.S. a continué à fonctionner sous l'éminente direction du Professeur Jeffreys et vous entendrez tout à l'heure son rapport. J'indiquerai ici que le Bureau de Strasbourg a continué à établir des fiches de renseignements macroséismiques avec éventuellement l'indication de l'épicentre macroséismique, fiches qui sont envoyées à Kew pour être utilisées pour le service de l'I.S.S. Un fichier en double est conservé à Strasbourg.

Conformément aux décisions de la Commission des Finances de l'Union notre Association a participé à la gestion de l'I.S.S. par une subvention de 1200 Livres soit 1.176.000 francs (soit 24 % de nos dépenses totales). Par ailleurs il convient de rappeler l'effort fait par l'U.N.E.S.C.O. en faveur de l'I.S.S. par l'intermédiaire de la Fédération des Services permanents: 2035 Livres en 1954, 1785 en 1955, 1428 en 1956, soit au total 5248 Livres (5.143.000 francs), somme supérieure au budget total de notre Association. Malheureusement comme vous le voyez la subvention accordée par l'U.N.E.S.C.O. a fortement diminué d'année en année et c'est une des questions que notre Commission de l'I.S.S. devra étudier.

J'ai ainsi passé en revue les principaux postes de dépenses de notre Association. Je voudrais maintenant évoquer quelques autres activités.

La Commission Séismologique Européenne s'est réunie à Vienne du 4 au 7 avril 1956. De nombreux collègues européens ont pu y assister, témoignant de l'intérêt qu'ils portent à cet organisme qui leur permet de se rencontrer et de discuter en dehors des Assemblées générales de l'Union, intérêt qui est encore renforcé lorsque ces Assemblées générales se tiennent hors d'Europe et ne permettent pas en raison des frais élevés de voyages à beaucoup de collègues d'y assister.

Les Comptes Rendus détaillés de la réunion de Vienne ont été très rapidement publiés, grâce à l'intervention de M. Laclavère, dans le Bulletin d'Information de l'U.G.G.I., News Letter N° 15, pp. 393-438.

Il convient ici encore de remercier l'U.N.E.S.C.O. qui a attribué une subvention qui a permis aux Membres de la Commission de se rendre à Vienne. L'U.N.E.S.C.O. voit avec faveur se tenir de telles réunions de travail. S'il fallait citer une justification parmi beaucoup d'autres je rappelerais que c'est à Vienne qu'ont été mis au point les principes de collaboration dans l'étude en commun de la structure des Alpes par l'exécution de grosses explosions. Des expériences ont pu être réalisées dans les Alpes françaises en 1956 avec la collaboration de collègues allemands et italiens. Madame Labrouste aura l'occasion de vous entretenir des résultats. Dans le même esprit des expériences vont être tentées dans quelques semaines en Bavière sous la direction du Professeur Reich.

Le Bureau de la Commission Séismologique Européenne comprend actuellement nos collègues Caloi, Président, Hiller, Vice-Président, et Peterschmitt, Secrétaire. De nouveaux Membres figurent à la Commission : le Prof. Savarensky y représente l'U.R.S.S. et le Prof. Zátopek la Tchécoslovaquie.

Mon rapport serait incomplet si je n'évoquais ici l'A.G.I., grande entreprise dont les buts ont conquis le grand public mais qui en fait n'est que la reprise élargie du travail déjà effectué au cours des deux précédentes Années Polaires. La séismologie où le travail de collaboration internationale se poursuit en fait de façon continue d'année en année n'avait pas d'abord été incluse dans les spécialités directement intéressées par l'Année Géophysique. Cependant le fait que de nombreuses expéditions pouvant emporter des séismographes allaient s'installer dans des régions comme l'Antarctique dont nous savons peu de choses au point de vue séismique a incité les organisateurs de l'A.G.I. à faire figurer également la séismologie dans le programme général de l'A.G.I. Votre Secrétaire Général a été invité à participer à la réunion tenue en septembre 1955 à Bruxelles par le C.S.A.G.I. Un groupe de travail a été constitué sous la direction du Professeur Beloussov et a pris des résolutions qui ont été diffusées par notre Bulletin mensuel.

Il nous a paru que notre Association ne pouvait rester à l'écart de cette grande manifestation géophysique et une Commission de l'Année Géophysique a été constituée après consultation par correspondance des différents Comités Nationaux. Le Prof. Beloussov a été choisi comme Président de cette Commission et je pense qu'il voudra en réunir ici ceux de ses Membres présents à notre Assemblée générale.

En collaboration avec le Prof. Beloussov un petit manuel d'instructions a été rédigé à l'usage des stations séismologiques. Une nouvelle rédaction de ce manuel est en cours de diffusion.

Une des tâches importantes des organisateurs de l'A.G.I. est de prévoir la concentration et la publication des innombrables données recueillies en 1957-1958. En ce qui concerne la séismologie les dispositions suivantes ont été prises: les bulletins réguliers et les dépouillements de l'agitation microséismique doivent être envoyés aux centres indiqués ci-dessous :

Centres A. Geophysics Branch
U. S. Coast and Geodetic Survey
WASHINGTON 25, D.C. (U.S.A.)

B. Institute of Aeroclimatology
Ulitsa Vorovskogo 33/35
MOSCOW G-69 (U.S.S.R.)

C. Bureau Central International de Séismologie
38, Boulevard d'Anvers
STRASBOURG (France)

Ces différentes questions pourront être précisées au cours de la réunion de notre Commission de l'A.G.I., réunion que présidera le Professeur Beloussov.

Au terme de son rapport, le Professeur J.-P. Rothé informe ses collègues qu'en raison de sa tâche devenue de plus en plus lourde à la Direction de l'Institut de Physique du Globe de Strasbourg il lui est difficile de conserver à la fois le Secrétariat général de l'Association et la Direction du Bureau international de Séismologie considéré maintenant comme service permanent de l'Association et subventionné comme tel par l'U.N.E.S.C.O. Le Professeur Rothé propose de continuer à assurer la marche du Bureau international. Si cette proposition est acceptée il y aurait lieu de modifier les statuts de l'Association qui ont prévu que les deux fonctions de Secrétaire général et de Directeur du Bureau central étaient assurées par la même personne.

ANNEXE AU RAPPORT DU SECRETAIRE GENERAL

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

Période 1954-1956

Recettes

	Frs. Français	Dollars équivalence	Livres équivalence	
Versement U.G.G.I.	3.684.770	—	(3760)	5580 £
Versement U.G.G.I.	1.029.000	—	(1050)	
Versement U.G.G.I.	264.600	* (756) *	(270)	
Versement U.G.G.I.	490.000	(1400)	(500)	
Intérêts (Pasadena)	81.158	(231,88)	—	
Intérêts (Strasbourg)	18.284	—	—	
Ventes	51.535	—	—	
Avances et divers	87.806	—	—	
Gain au change	729	—	—	
	5.707.882			

* 756 dollars (encaissés le 28 décembre 1953) ont été retranchés du compte 1953 et repris dans le compte 1954.

Dépenses

Subvention à l'I.S.S.	1.176.000	—	(1200)
Subvention au Bulletin mensuel	1.051.611**	—	—
Secrétariat: traitement	677.802	—	—
poste	105.854	—	—
divers	63.582	—	—
Frais de voyage	4.540	—	—
Frais de publications	1.788.878	—	—
Assemblée de Rome	37.826	—	—
	4.906.093		

** voir plus loin comptes spéciaux du Service permanent du Bulletin.

Balance au 1er janvier 1954 :

Strasbourg	254.944	—	—
Cambridge	2.573.530	—	(2626-2-3)
Pasadena	813.400	(2324,01)	—
	3.641.874		
Recettes 1954-1956	5.707.882		
	9.349.756		
Dépenses 1954-1956	4.906.093		
Reste au 31 décembre 1956	4.443.663		
L'excédent est réparti ainsi :			
Strasbourg	1.153.003	—	—
Cambridge	1.641.500	—	(1675-2-3)
Pasadena	1.649.160	(4711,89)	—
	4.443.663		

Le taux de change utilisé est : 1 £ = 980 francs = 2,8 dollars, 1 dollar = 350 francs.

COMPTES SPECIAUX DU SERVICE PERMANENT DU BULLETIN MENSUEL

Période 1954—1956

Dépenses

Traitements et impôts (M. Marzi)	1.862.413 fr.
Traitements auxiliaires	193.000 »
Papier, tirages	1.012.418 »
Frais postaux	180.000 »
	3.247.831 fr.

Recettes

Versements UNESCO	2.196.220 fr.
Versement Association	1.051.611 »
	3.247.831 fr.

Le versement Association est la différence entre les dépenses du Bulletin et les Recettes (versements UNESCO).

Je soussigné, OTT Georges Edmond, Percepteur des droits universitaires à Strasbourg, déclare avoir examiné la comptabilité ci-dessus pour la période 1954-1956 et n'avoir aucune observation à formuler à son sujet.

Strasbourg, le 24 février 1957.

Signé : *E. Ott.*

3. Election of a Finance Committee

Dr. De Bremaecker gives a summary in English of the report of the Secretary General. *President Bullen* expresses the thanks of the Association to the Secretary General for his report, and hands over the chair to *Dr. Stoneley.*

There is no discussion on the finance of the Association. A committee of three members is elected to check the accounts : *P. Byerly, B. Gutenberg,* and *J.H. Hodgson.*

4. Discussion of the report by the Secretary General

The discussion concerns the separation of the functions of Secretary General and of Director of the Bureau Central International de Séismologie (see the Statutes of the Association, Comptes Rendus No 10, pp. 143-152).

Dr. Stoneley suggests P. Byerly, B. Gutenberg, and J. H. Hodgson to consider changes of statutes required.

Prof. Gutenberg asks if Prof. Rothé would consider continuing in both positions if help could be supplied.

Prof Rothé replies that it is difficult to continue this very heavy work, and that a paid Secretary General would be hard to obtain for a small salary.

Dr. Stoneley supports Prof. Rothé's request for division of the duties.

Prof. Gutenberg proposes that committee should be composed entirely of chief delegates, as a constitutional rather than a scientific matter is involved.

Prof. Shneiderov suggests that Prof. Rothé agrees to select a suitable person in Strasbourg to carry on a part of the secretarial work. In this way Prof. Rothé would be disloaded, and the secretarial duties would be conveniently and effectively carried out as Prof. Rothé did it for years.

Dr. Stoneley again suggests a small committee.

Dr. Hodgson says that all of the original committee were North Americans. It should also be others.

Prof. Bullen : The problem is only to explore the situation. The formal decision will arise later. Therefore I propose a wider committee — if possible from different continents.

Dr. Stoneley proposes a committee of three members : *Prof. Benioff, Prof. Keilis-Borok, Dr. De Bremaecker.*

The Assembly agrees to this composition of an exploratory committee.

5. Report of the President of the Committee for the I.S.S.

Sir Harold Jeffreys presents his report :

As this will be my last report, a general summary of events since I undertook the Directorship will be appropriate. Dr. Stoneley's Presidential Address at Brussels (1951) dealt largely with the history of the I.S.S. and may be consulted for other information.

I became Director in December 1946. At that time, largely owing to shortage of staff during the war, the last part issued was for 1934 July-September. Mr. Hughes, with two assistants, kept up four parts a year for some time, and when we engaged another assistant the number gradually increased to seven. This rate has been maintained since 1951. An informal meeting at Brussels recommended an attempt to raise the rate to 9 parts per year, but this has not been successful. The last part issued (up to March 1957) is for 1949 April-June. The arrears have thus been greatly reduced, but at the present rate it will still be 7 years before they can be reduced to 3 years, which is probably the minimum attainable. If 9 parts per year could be published, this object would be achieved in 4 years.

In fact there will be considerable difficulty in maintaining even the present rate in future unless the financial support is increased. Grants from Unesco and H.M. Treasury are the principal source of income, but fluctuate greatly in amount, and in most years the amounts have not been known till April or May ; whereas the financial year begins in November. Expenses have greatly increased in the last few years. This is mostly due to the increase in size. There was a slight reduction during the later war years, but this has now been more than made up, on account of the increase in the number of stations reporting. The sizes of recent volumes and the cost of printing may be summarized as follows :

	Printing cost	*Volume*	*Pages*
	£	1944	358
1953-4	1172	1945	422
1954-5	1457	1946	602
1955-6	2000	1947	560
		1948	710

For comparison, volumes for pre-war years were : 1937, 645 pp.; 1938 (an abnormally large one) 732 pp.; 1939, 529 pp.

The total grants and expenses have been as follows :

	Unesco	*H.M. Treasury*	*IUGG and IASPEI*	*Expenditure*
	£	£	£	£
1953-4	2035	1000	200	3376
1954-5	1785	2000	0	3704
1955-6	1428	2000	1200*	4460

It is clear that the grants do not cover the present cost of publication and preparation, and at least £4500 a year is needed. To accelerate to 9 parts per year would need about £1100 more, though this would naturally be only for about four years, after which (apart from further possible rises in prices) the income needed would drop to about £3000 per year.

On a previous occasion we investigated the possibility of using a method of duplication by photolithography instead of printing; expert advice was given by members of the Royal Society's staff. On consideration of the special conditions, however, we found that the saving, if any, would be too small to justify abandoning our present printers, especially as they are familiar with the work.

The use of high-speed computing machines has also been considered, but it would have the disadvantage that different stations report for every earthquake, and in different detail, so that it would be impossible to arrange a regular programme. Also the longest part of the work is not in the actual computation, but in the preliminary copying of station records on to cards so that all the data for each earthquake can be kept together.

The usefulness of the I.S.S. is twofold. In the first place it is a regular record of seismic activity over the world, and it is for that purpose that most countries have seismological stations at all. In the second, it has been the basis of considerable advances in general seismology, and its use for that purpose is far from exhausted. The Jeffreys-Bullen 1940 tables gave agreement with the data in the

* Refers to whole period 1954-6, but received after the end of the financial year 1955-6.

sense that any other tables, while they might fit some earthquakes better, would certainly fit others worse. They made no attempt to allow for regional differences in travel times. Since their publication it has been found that there is a systematic difference in travel times of P between Europe and North America, where the velocity up to 15° is about 8.1 km/sec, and Japan, where it is about 7.8 km/sec. Exploration of the ocean floor (mainly Atlantic and North Pacific) usually gives the former value. The tables, however, fit Japan, and as the times of S and the core wave SKS have been mainly derived from Japanese deep-focus earthquakes, they also refer essentially to Japanese earthquakes. At distances over 30° it appears that the times of P need a reduction of 1 to 2 sec. at all distances, and the behaviour of the 20° discontinuity also depends on the region. Unfortunately its detailed study is difficult, because in any region there is a range of distance where the times are still in doubt. So long as we were prepared to assume that all regions are alike, data from one could be used to fill in the gaps left by another, but this is no longer legitimate when we are concerned with differences between regions. The only procedure at present is to look for suitable earthquakes in the I.S.S. We also need more near earthquake studies from Japan. A few really well buried large explosions could of course give the answer more quickly, but those in a position to arrange such explosions show no disposition to provide them.

I should recall that when I undertook the Directorship of the I.S.S. it was strongly recommended by the I.A.S. and the British National Committee that the work should be transferred to Cambridge, so that the data would be accessible to research workers before publication. Though all seismologists must be grateful to the Director of the Meteorological Office for granting us accommodation at Kew, this aim should not be forgotten.

In taking leave of the I.S.S. I must express my thanks first to Unesco and H.M. Treasury for financial support ; to Dr. Stagg and M. Laclavère, as General Secretaries of the Union ; to Professor Rothé; and to Dr. Stagg and Dr. G. D. Robinson, as Superintendents of Kew Observatory, who have relieved me of many administrative cares. The printers, the Isle of Wight County Press, have been unfailingly helpful. Above all I must thank Mr. J. S. Hughes, Assistant Director, who has been responsible for the whole of the preparation and also for many decisions that would normally have to be made by the Director.

HAROLD JEFFREYS.

APPENDICES TO THE REPORT BY SIR HAROLD JEFFREYS

I. — *REPORT OF THE DIRECTOR OF THE I.S.S. FOR 1953 NOVEMBER 1 — 1954 OCTOBER 31.*

The accounts for the year are given herewith.

Mr. Hughes and I attended the Rome meeting of the I.U.G.G. Part of my expenses was covered by a grant from the Royal Society; the remainder appears in the accounts under « travelling ».

During the year seven parts were issued, namely those for 1943 Oct.-Dec. up to 1945 April-June.

The parts for the war years up to 1942 were not much smaller than those in previous years, but those for 1943-4 are substantially smaller. It remains to be seen whether the rate of preparation can be maintained when the post-war recovery takes place. The printers have been most helpful in increasing the rate of printing to keep pace with preparation, and a letter of thanks has been sent to them.

A mathematical graduate, Mr. J. H. McDonnell, was engaged last year but left after six months to take up an industrial post. A new one, Mr. J. H. Wavish, was engaged after the close of the year.

I reported at Rome that I would have to retire from my University post in 1956. The retiring age has now been raised to 67, so I need not retire till 1958. Nevertheless I wish to resign the Directorship of the I.S.S. at or before the next meeting of the I.U.G.G.

HAROLD JEFFREYS.

Financial Statement for the year ended 31st October 1954

Receipts

	£	s.	d.	£	s.	d.
Grants :						
United Nations Educational, Scientific and Cultural Organisation	2,035	14	4			
H.M. Treasury (per Royal Society)	1,000	—	—			
International Geodetic and Geophysical Union	200	—	—	3,235	14	4
Sales of Literature				70	—	7
Deposit Account Interest to 30th June 1954				44	3	4
Total Receipts				3,349	18	3
Cash at Bankers and Cash in Hand 31st October 1953				2,139	10	11
				£ 5,489	9	2

Payments

	£	s.	d.	£	s.	d.
Salaries and Allowances (less Staff Superannuation Contributions)				1,704	5	4
Superannuation Contributions				169	10	—
National Insurance				81	8	2
Printing				1,172	10	9
Stationery and Postage (including Typing)				64	—	3½
Bank Charges and Cheque Books				5	4	—
Maintenance of Calculating Machines				46	9	4½
Accountancy Charges				3	13	6
Miscellaneous Expenses				8	7	6
Travelling Expenses				121	5	3
Total Payments				3,376	14	2
Cash at Bankers 31st October 1954:						
Deposit Account	1,905	16	3			
Current Account	198	6	2			
Petty Cash in Hand 31st Oct. 1954:						
London		16	3½			
Cambridge	7	16	3½	2,112	15	—
				£ 5,489	9	2

Auditors' Certificate

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

Norwich Union Buildings
Downing Street, Cambridge
10th December 1954.

Peters, Elworthy and Moore
Chartered Accountants.

II. — *REPORT OF THE DIRECTOR OF THE I.S.S. FOR 1954 NOVEMBER 1 — 1955 OCTOBER 31.*

During the year seven quarterly parts have been published, namely those for 1945 July to 1947 March, and also two index catalogues of epicentres. Two members of the staff have left and a new young man has been engaged.

The financial situation continues to give much ground for anxiety. The grants from Unesco were £2035 in 1953-54 and £1785 in 1954-55. The amount for 1954-55 is the result of allocation to the I.S.S. by the General Secretary of a higher proportion of a reduced grant from Unesco to the Union, and it is likely that the allocation in 1955-56 will be nearer to £1000.

There is no possibility of reducing expenses, since the contribution from the British Treasury is conditional on the production of seven parts per year. Unless the Unesco grant is restored to its former amount we shall have a deficit of the order of £ 1000 per year.

In 1945 I emphasized the need for an assured income and for the transfer of the work to Cambridge. This was strongly supported by the International Seismological Association. In the urgent circumstances of the time I agreed as a temporary measure to undertake the direction without these conditions being satisfied. But in any case I cannot continue beyond the next meeting of the I.U.G.G. in 1957, and I must emphasize now the unfairness of expecting any Director to undertake a task of a permanent nature in the conditions that I have had to endure for ten years.

HAROLD JEFFREYS.

Financial Statement for the year ended 31st October 1955.

Receipts

	£	s.	d.	£	s.	d.
Grants :						
H.M. Treasury (per Royal Society)	2,000	—	—			
United Nations Educational, Scientific and Cultural Organisation	1,785	14	3	3,785	14	3
Sales of Literature				61	16	9
Deposit Account Interest to 30th June 1955				31	11	8
Total Receipts				3,879	2	8
Cash at Bankers and in Hand 31st October 1954				2,112	15	—
				£ 5,991	17	8

Payments

	£	s.	d.	£	s.	d.
Salaries and Allowances (less Staff Superannuation Contributions)	1,791	17	6			
Superannuation Contributions	253	1	—			
National Insurance	87	5	1	2,132	3	7
Printing				1,457	11	2
Stationery and Postage (including Typing)				75	10	5
Bank Charges and Cheque Books				4	14	7
Maintenance of Calculating Machines				17	10	8
Accountancy Charges				3	13	6
Miscellaneous Expenses				11	4	5
Travelling Expenses				2	—	—
Total Payments				3,704	8	4
Cash at Bankers 31st October 1955 :						
Deposit Account	2,323	2	2			
Less : Overdraft on Current Account	40	6	9			
	2,282	15	5			
Petty Cash in Hand 31st October 1955 :						
London	4	3	3			
Cambridge		10	8	2,287	9	4
				£ 5,991	17	8

Auditors' Certificate

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

Norwich Union Buildings,
Downing Street,
Cambridge.
9th January 1956.

Peters, Elworthy and Moore
Chartered Accountants.

III. — *REPORT OF THE DIRECTOR OF THE I.S.S. FOR 1955 NOVEMBER 1 — 1956 OCTOBER 31.*

During the year seven parts have been issued, the last being for 1948 October - December.

The accompanying financial statement shows that the balance in hand has decreased during the year from £ 2287 to £ 1369, so that there has been a loss of about £ 900 on the year's working. This is largely due to a rise in the cost of printing. The following tables show the expenditure on printing and the number of pages in the volumes included ; each year corresponds to seven quarterly parts issued :

	£	Volume	Pages
1953-4	1172	1944	358
1954-5	1457	5	422
1955-6	2000	6	602
		7	560
		8	710

There has been an increase in the printers' charge per page, but the chief reason for the increase in the cost has been the increase in the size of the volumes. This is mostly due to the resumption of work at stations that were inactive during the war, but partly to the creation of new stations. For comparison, pre-war volumes were : 1937, 645 pp.; 1938 (an abnormally large one) 732 pp.; 1939, 529 pp.

Most of the rest of the loss is accounted for by the reduction of the Unesco grant from £ 1785 to £ 1428. It is clear that continuation of the work in a way that does justice to the observational material will require an increase of the grants from all sources to about £ 4500. If the grant from H.M. Treasury continues at £ 2000, this implies that £2500 will be needed from international sources.

I should add that the printers have offered to increase the rate of printing if we can supply manuscript at a greater rate. For some years we have been producing seven parts per year. At an informal meeting in Brussels in 1951 it was resolved to attempt to produce nine, and this would still be desirable ; but the additional cost would be at least £ 700 a year. The present lag of $7\frac{3}{4}$ years could then be reduced to 3 years in about four years, and thenceforward a considerable reduction in cost would be possible.

On a previous occasion we investigated the possibility of using a method of duplication instead of printing ; expert advice was given by members of the Royal Society's staff. On consideration of the special conditions, however, we found that the saving, if any, would be too small to justify abandoning our present printers, especially since they are specially accustomed to the work.

I wish to resign the Directorship of the I.S.S. as from the Toronto meeting next year. Dr. R. Stoneley has stated that he would be willing to act.

The present staff consists of Mr. J. S. Hughes, Mr. J. H. Wavish, Mr. J. L. B. Biddle, and Mrs. I. E. Sanders.

HAROLD JEFFREYS.

Financial Statement for the year ended 31st October 1956.

Receipts

	£	s.	d.	£	s.	d.
Grants :						
H.M. Treasury (per Royal Society)	2,000	—	—			
United Nations Educational, Scientific and Cultural Organisation	1,428	11	4	3,428	11	4
Sales of Literature				43	2	8
Deposit Account Interest to 30th June 1956				50	5	10
Total Ordinary Receipts				3,521	19	10
Received on surrender of Superannuation Policy (less paid to employee)				21	—	—
Cash at Bankers and in Hand 31st October 1955				2,287	9	4
				£ 5,830	9	2

Payments

	£	s.	d.	£	s.	d.
Salaries and Allowances (less Staff Superannuation Contributions)	1,983	18	3			
Superannuation Contributions	277	16	—			
National Insurance	112	4	11	2,373	19	2
Printing				2,000	—	3
Stationery and Postage (including Typing)				41	2	4
Bank Charges and Cheque Books				5	4	—
Maintenance of Calculating Machines				25	6	9
Accountancy Charges				4	11	6
Miscellaneous Expenses				8	6	10
Travelling Expenses				2	—	—
Total Payments				4,460	10	10
Cash at Bankers 31st October 1956 :						
Deposit Account	1,373	8	—			
Less : Overdraft on Current Account	4	10	4			
	1,368	17	8			
Petty Cash in Hand 31st October 1956 :						
London		5	5			
Cambridge		15	3	1,369	18	4
				£ 5,830	9	2

Auditors' Certificate

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

Norwich Union Buildings,
Downing Street, Cambridge.

16th November 1956 PETERS, ELWORTHY & MOORE
Chartered Accountants

IV. — *REPORT OF THE DIRECTOR OF THE I.S.S. FOR 1956 NOVEMBER 1 — 1957 OCTOBER 31.*

(This report was prepared after the Toronto Assembly, but is included here for completeness)

Sir Harold Jeffreys relinquished on 31 Oct. 1957 the post of Director, which he has held since 1946. In succeeding him I would like to add my personal expression of thanks, to those accorded to him at Toronto last September by the International Association of Seismology and the Physics of the Earth's Interior.

The accompanying financial statement shows that the balance in hand has increased by about £ 555 since a year ago. The expenditure on printing, however, has diminished by about £ 450, inasmuch as only 4 numbers were issued and paid for during the past year. Two further quarterly parts of the I.S.S. will appear very shortly, and will in effect more than account for the increased balance of £ 555. Thus a realistic view of the year's operations would be that there has been a net loss rather than a net gain.

This loss, attributable in part to the reduction of the U.N.E.S.C.O. grant, would have been more marked had not the I.S.S. received a special allotment of £ 1200 from the International Association of Seismology and Physics of the Earth's Interior as its share of the special subvention allotted by I.U.G.G. in respect of the triennium 1954-56. The set-back in publication this year arises from two causes, (i) there is more material to be dealt with than formerly (ii) it has not yet proved possible to replace one of the assistants who left.

The difficulties under which the I.S.S. has struggled for some years need to be emphasised. The world-wide importance of the compilation of the I.S.S. has never been in dispute : our detailed knowledge of the interior of the Earth, as exhibited in the work of Jeffreys, Bullen and others, is based directly on the I.S.S. The work is run most economically, and careful consideration has always been given to reducing costs of production without impairing the completeness of the record. For some years H. M. Treasury has contributed £ 2,000 annually, as the U.K. contribution to international seismology, and not only is the project housed free of charge by Kew Observatory (a national meteorological observatory), but in addition the Director of that observatory provides the services of a member of his Staff to carry out the administrative duties connected with payment of Staff. Thus, the British contribution has been maintained, while the contribution from international sources to this international project has progressively diminished.

As stated by Sir Harold Jeffreys in his report for the preceding year, this unsatisfactory state of affairs needs immediate attention. The salary it is possible to offer to a member of the Staff is not such as to make it at all easy to find suitable workers, and the urgent need to take on extra computers to overtake arrears is frustrated by the lack of any guarantee that the income of the I.S.S., already badly hit by rising costs, will be maintained even at its present inadequate level for the next few years.

At Toronto the Committee for the I.S.S., Bullen (Australia), Gutenberg (U.S.A.), Hodgson (Canada), Jeffreys (U.K.), Kondorskaya (U.S.S.R.), Lehmann (Denmark), Murphy (U.S.A.), Rothé (France), Stoneley (U.K.), considered it essential for the satisfactory preparation of the I.S.S. that an annual sum of 10,000 dollars should be provided from international sources, and this view was unanimously endorsed as a resolution of the Association of Seismology and the Physics of the Earth's Interior.

The present Staff consists of Mr J. S. Hughes, Mr J. H. Wavish, Mr J. L. B. Biddle and Mrs I. E. Sanders, with a small amount of additional part-time work from time to time. In taking over the Directorship I would like to pay a tribute to the devotion with which the Staff have, over a number of years, worked to maintain the high level of this important scientific production.

ROBERT STONELEY,

29th Nov. 1957 Hon. Director, I.S.S.

Financial Statement for the year ended 31st October 1957.

1955/56 *Receipts*

£	s.	d.		£	s.	d.	£	s.	d.
			Grants :						
2,000	—	—	H. M. Treasury (per Royal Society)	2,000	—	—			
1,428	11	4	United Nations Educational, Scientific and Cultural Organisation	1,071	8	7			
—	—	—	International Association for Seismology and the Physics of the Earth's Interior	1,200	—	—	4,271	8	7
43	2	8	Sales of Literature				129	3	1
50	5	10	Deposit Account Interest				52	15	1
3,521	19	10	Total Ordinary Receipts				4,453	6	9
21	—	—	Received on surrender of Superannuation policy (less paid to employee)						
2,287	9	4	Cash at Bankers and in Hand 31st October 1956				1,369	18	4
£5,830	9	2					£5,823	5	1

1955/56			*Payments*						
£	s.	d.		£	s.	d.	£	s.	d.
			Salaries and Allowances (less Staff Superannuation Contributions)						
1,983	18	3		1,890	10	—			
			Superannuation Contributions						
277	16	—		237	6	—			
112	4	11	National Insurance	114	1	8	2,241	17	8
2,000	—	3	Printing				1,553	3	6
			Stationery and Postage (including Typing)						
41	2	4					67	7	—
5	4	—	Bank Charges and Cheque Books				1	—	—
			Maintenance of Calculating Machines						
25	6	9					17	8	—
4	11	6	Accountancy Charges				6	6	—
10	6	10	Miscellaneous and Travelling Expenses				9	7	3
4,460	10	10	Total Payments				3,898	9	5
			Cash at Bankers 31st October 1957 :						
1,373	8	—	Deposit Account	1,597	11	8			
—4	10	4	Current Account	324	3	6			
				1,921	15	2			
			Petty Cash in Hand 31st October 1957 :						
	5	5	London	3	—	6			
	15	3	Cambridge		Nil		1,924	15	8
£5,830	9	2					£5,823	5	1

Auditors' Certificate

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

Norwich Union Buildings,

Downing Street, Cambridge.

17th December 1957.

PETERS, ELWORTHY & MOORE
Chartered Accountants

6. Discussion of Sir Harold Jeffreys' report. Re-constitution of the I.S.S. Committee.

President Bullen, in the chair, expresses the thanks of the Association to Sir Harold Jeffreys for his report and for his great services as Director of the I.S.S. (applause).

Prof. Gutenberg : Pasadena is checking epicenters of special interest and of deep-focus earthquakes up to 1949 now. Most I.S.S. bulletins contain earthquakes of special interest which would often be missed. The I.S.S. results agree very well with Pasadena. The information contained in the I.S.S. bulletins is of great importance.

Prof. Richter : Among the chief services of the I.S.S. is its placing on permanent records of data which may later be used for research purposes which we cannot now even guess. Data published by Turner in the early years of the I.S.S. were invaluable for investigations 20 years later, in spite of the incompleteness of Turner's interpretations. It is most improbable that our interpretations are now complete.

Prof. Bullen emphasizes the continual struggle for finance. Executive meeting of the I.U.G.G. last year revealed difficulty of getting more funds. It is of vital importance that I.S.S. is kept supplied. The incoming Director should not be made to start in a bad position.

The following discussion concerns the question if stations should send their data on cards to I.S.S. In reply to a number of questions from several delegates, Mr. Hughes explains his opinion on this point.

Mr. Hughes : The question is complicated. Many of our stations are parts of an organisation. Each station would have to be copied separately. — More prompt reception is not of much help. The big point is that the data should be workable right away. — The information wanted is that which is given in the I.S.S. now. The usual practice would be one card per day per station. — It is imperative for uniform size of the cards : 4"×3". We could supply all cards or samples. — Some stations record up to 40 unidentified onsets per quake. These are often cut out.

Dr. Walter: With the increase in number of stations and sensitivity of instruments may be we should systemize our methods of reporting data.

Prof. Gutenberg: Small quakes are specially interesting. The determinations of the large shocks are sufficiently good already.

Mr. Murphy : Because of the tremendous publication problem in preparing the I.S.S. it is suggested that some very definite proposals be given to the I.S.S. whereby the stations may be helpful in submitting earthquake reports on forms that will reduce the clerical efforts of the I.S.S.

Prof. Rothé : This should be discussed by a small committee.

Dr. Stoneley : There is a Committee for I.S.S. to be reconstituted.

After this the Committee for the I.S.S. is reconstituted. *Dr. Stoneley* is nominated as the new Director of the I.S.S. to succeed *Sir*

Harold Jeffreys, who remains as a member of the Committee. *Prof. Gutenberg, Dr. Hodgson,* and *Miss Lehmann* are already members of the Committee. *Prof. Bullen* is nominated so that he stays on when he is no longer president. *Mrs. Dr. Kondorskaya* and *Mr. Murphy* are nominated to replace Father Macelwane and Dr. Vesanen. The President and the Secretary General are automatically members of the Committee. The new Director, *Dr. Stoneley,* and the new members of the Committee, *Prof. Bullen, Mrs. Dr. Kondorskaya,* and *Mr. Murphy,* are elected unanimously by the Assembly.

Prof. Bullen reads a message from *Dr. Wadati,* proposing a vote of thanks to U.S.C.G.S. for their seismological service. Proposal is made from chair and seconded by *Father Lynch.*

Dr. De Bremaecker says that his institute has the intention of using punched cards in the I.B.M. system for the representation of earthquake data and offers these cards to those interested.

Prof Richter in reply to questions by *Prof. Rothé* and *Dr. De Bremaecker* says that at Pasadena there exists a punched card file in the I.B.M. system for all epicenters in the book « Seismicity of the Earth », but not for others.

Prof. Gutenberg proposes that the Assembly votes strongly in favour of continuing I.S.S.

The vote is unanimous in the Assembly.

Father Lynch suggests the vote be transmitted to the financing organisations.

7. Discussion concerning re-organisation of I.A.V.

President Bullen, in the chair, gives an introduction : The problem involves me, as it has been raised by a special I.U.G.G. committee, of which I am a member, and I have been asked to consult the Association. The resolution is very far-reaching and controversial. The Association of Volcanology wants to include geochronology and constitution of the Earth. This overlaps our Physics of the Earth's Interior program. The question is how far Volcanology will impinge on our activities. It is of vital importance that I have the views of the Association in this matter.

Texts are read in English and French of a recommendation by *Prof. Rittmann,* President of I.A.V., presented at a meeting of the Bureau and the Executive Committee of I.U.G.G. in Paris April 17-21, 1956. Rittmann's review of the science of volcanology was at that time studied by a small committee. The following recommendations were made by the Council of the Union.

1. Que l'on change le nom de l'Association Internationale de Volcanologie en Association Internationale de Volcanologie, Géochronologie et de Composition de la Terre mais que l'on garde le titre du Bulletin Volcanologique.

2. Que le champ d'action de l'Association Internationale de Volcanologie soit agrandi et comprenne la Géochronologie et la Composition de la Terre.

3. Que des commissions pour la Géochronologie et la Composition de la Terre soient créées dans l'Association Internationale de Volcanologie.

4. Que le Comité Exécutif de l'Association Internationale de Volcanologie comprenne le Président, le Secrétaire Général et trois Vice-Présidents, afin que chaque Commission soit représentée par un des Vice-Présidents :

— Commission de la Paléovolcanologie déjà existante,

— » » Géochronologie,

— » » Composition de la Terre.

The following points 5-9 in the recommendations concern suggested discussions of these propositions at Toronto, continuation of the Catalogue des Volcans Actifs and supplementary volumes, increased collaboration with other associations, organisation of symposia. Complete texts have appeared in Bulletin de l'U.G.G.I., No. 14, pp. 201-205.

Texts are also read of the comments made by some national committees :

a) The British National Committee (Sub-Commission for Volcanology) is against the recommendations 1-4, but is favourable to the following propositions.

b) United States National Committee says it has been recognized that I.A.S.P.E.I. and I.A.V. eventually could form a single Association for the Interior of the Earth.

c) The French National Committee gives the following recommendation :

« Considérant l'intérêt qui s'attaque à grouper ensemble les branches des Sciences Géodésiques et Géophysiques qui sont susceptibles de l'être, plutôt qu'à les disséminer dans des organisations différentes, le Comité National Français recommande la création d'une Association Internationale unique qui grouperait tous les problèmes de *Géophysique interne* et qui pourrait comprendre *trois* Sections jouissant d'une structure propre scientifique et administrative, mais avec un *Bureau Commun :* Président, Vice-Président et Secrétaire Général :

a) Section de *Séismologie* (proprement dite).

b) Section de *Volcanologie* (proprement dite).

c) Section de *Physique de l'Intérieur de la Terre,* qui pourrait s'intéresser en particulier aux problèmes de Géochronologie, de Géothermie, de Radioactivité et de Composition de la Terre.

Le budget de la nouvelle Association devrait être au moins égal à celui des deux Associations existant actuellement ».

Complete texts will be found in a publication « Réunion du Conseil de l'Union Géodésique et Géophysique Internationale », dated September 2, 1957, under article 4C (distributed during the Toronto Assembly).

The session is closed at 12.30.

SECOND SESSION

WEDNESDAY, SEPTEMBER 4 (afternoon)

Program

7. — Discussion concerning re-organisation of I.A.V. (cont.).

8. — Discussion on the place of radioactivity in I.U.G.G.

The session is opened at 02.15 p.m. with *President Bullen* in the chair.

7. Discussion concerning re-organisation of I.A.V. (cont.)

Prof. Rothé says he is personally against the text of the letter from the French National Committee. Also French volcanologists do not agree to it.

Prof. Bullen : We still have to hear the Russian view.

Prof. Beloussov : We have thought about the problem without taking any definitive decisions. The problem has many sides. One is that volcanic phenomena are closely bound to other geologic and geophysical phenomena in and under the crust, e.g. geosynclines, questions of the early evolution of the earth, geothermal processes. It is very difficult to cover all this by one title ; the nearest thing is « Tectonophysics » because this is a vague term. — From another side it seems that certain questions studied in our Association do not belong there. Theoretical seismology is very different from general tectonics, and our Association attracts people of widely different interests. Our Association ought to define its program more precisely than now. — Our proposal is to create a new Association, for which the title can be discussed, say « Volcanology and Tectonophysics ». This new Association should attract new people, e.g. geologists and others interested in the boundary problems of geology and geophysics. The methods are different : in our present Association physical and mathematical, in the new Association geological and geophysical in general.

Prof. Bullen says that we have to add the division of Chemistry to that of Physics and Geology, and asks the Assembly to discuss the problem as fully as possible.

Prof. Gutenberg, as a former president of the Committee of P.E.I., says that this committee came close to the idea of three

Associations : Seismology ; Physics and Chemistry of the Earth's Interior; Volcanology. This was turned down, for financial reasons. An attempt to form one large Association of the three was opposed by I.A.V. The situation has not changed since then. Prof. Gutenberg suggests : (1) three Associations or (2) one Association with three sections.

In a discussion by *Sir Harold Jeffreys, Prof. Rothé,* and *Dr. Stoneley* it is mentioned that the International Geological Conference is private and that there is no Union of Geology in the Council of Scientific Unions.

Dr. Russell : As a geochemist among seismologists I feel out of place. My problems hardly ever deal with P.E.I., which ties up with seismology. We have a group concerned in surface features. Volcanoes are also surface features. I can see no grounds for binding geochemistry and geochronology with seismology — but I can see strong reasons for binding them to volcanology.

Prof. Bullen : Geochemistry is central point. In the deep interior we have to use chemistry. Birch has to tie chemistry and physics together. Notable experimenters, e.g. high pressure workers, have had to bring these subjects included with P.E.I., or excluded ?

Prof. Press emphasizes the drawback of having several simultaneous programs, as many people are interested in several fields. If this happened we would soon face the problem of having a new Association to include people interested in Seismology, Tectonics, and Physics of the Earth's Interior.

Prof. Gutenberg : I feel with Dr. Bullen that we have geochemists interested in the interior, and those interested in surface rocks only. Some volcanologists are interested in the deep interior, whereas others are concerned only with visible features. — I think the situation is changing. I hope that soon a majority of volcanologists will be interested in the chemistry of large parts of the earth. We have a very good opportunity and an obligation to work for a good solution — not one which will have to be changed again in three or six years time.

Father Ingram suggests using P.E.I. and Chemistry as distinctions, and finds three Associations, as suggested by Prof. Gutenberg, a good idea. As a second preference he suggests (1) Seismology and P.E.I. and (2) Volcanology and Geochemistry. Upon a question by Prof. Bullen, Father Ingram agrees to the imprecise nature of the term Geochemistry and suggests Chemistry of the Interior of the Earth as alternative.

Prof. Benioff emphasizes the difference in technique used. For the interior of the earth, the worker is using theoretical and practical physics, and he is therefore a geophysicist. At the surface he is using techniques of chemical analysis, and then he is a geochemist.

Prof. Bullen asks for opinions on Geochronology. Is it a large enough subject for inclusion in a title ?

Dr. Stoneley : These things must proceed by growth. We should not try to set up machinery in anticipation of expected developments.

I should therefore like to side with Prof. Rothé and Prof. Gutenberg, and allow the matter to rest until the present trends have further defined the field.

Dr. Russell : There are many people working on Geochronology (26 papers during this Assembly) and they have no home. I think a home should be found in Geophysics, so we get more papers and more discussion.

Dr. Carder : The Geochronology people should choose their Association if it is one of the others. Of course it would be different if they had their own Association.

Prof. Shneiderov supports what Dr. Stoneley said and suggests postponement to the next Assembly. The activities of the existing Associations should be coordinated to avoid overlapping.

Prof Bullen : We all agree Geochronology must have a home. But is it so important as to need a title ?

Dr. Stoneley suggests having a rapporteur in Geochronology in our Association to assist the development of the subject.

Dr. Russell thinks this suggestion is a step in the right direction, but is not sure whether the rapporteur should be in I.A.S.P.E.I. or in I.A.V. There is probably more room in I.A.V.

Prof. Bullen summarizes the discussion in the following words.

On the proposition that the scope of the Association of Volcanology should be extended, the feeling of the meeting appears to be as follows :

1) On the composition of the earth, so far as the deep interior is concerned, we feel that it would be unnatural and undesirable to separate questions of chemical composition from questions of the physics of the earth's interior.

2) On Geochronology, I inferred that we agreed the case is adequately met by having a rapporteur in at least one Association, rather than going to the length of including it as part of an Association title. Several members thought that there should be a rapporteur on Geochronology in our Association.

3) I inferred from the discussion that we felt that no radical change should be made in the titles of the two Associations at this stage, and that the position might well be reviewed some few years later when some of the newer activities have developed more fully.

4) I noted the suggestion of Prof. Beloussov that Tectonophysics might well be added to the name of the I.A.V. This received some support and no opposition.

8. Discussion on the place of radioactivity in I.U.G.G.

Prof. Bullen summarizes the document submitted to the central Committee (article 4 D in « Réunion du Conseil de l'Union Géodésique et Géophysique Internationale », dated September 2, 1957, and distributed during the Toronto Assembly). After describing the various ways in which the study of radioactivity has relations to I.U.G.G. and the actions already taken, the article 4 D ends with the following conclusion :

« Devant l'importance accrue de la Radioactivité et face à l'action des organismes précités, que doit faire l'Union ?

Le Conseil et le Comité exécutif de l'Union, au cours de leur réunion d'avril 1956 à Paris, ont chargé un Comité de faire des propositions sur les mesures à prendre pour que l'Union soit tenue au courant de ces problèmes et de leur évolution. Ce Comité, composé de Prof. Ramanathan, Prof. Rossby et Prof. Mosby n'a pu se réunir avant la XI^e Assemblée Générale. Son travail d'information reste donc à faire.

Mais ce stade d'information doit aussi être dépassé. Et il est nécessaire que le Conseil et le Comité exécutif, ne s'y arrêtant pas, décident de la politique à suivre en matière de radioactivité.

Le problème est assez délicat. Chaque Association doit-elle simplement avoir son ou ses spécialistes qu'elle déléguera auprès des autres organismes ? Doit-on créer une Commission mixte entre les Associations intéressées (AIMAP, AIOP, AIH et AIV), Commission chargée d'organiser des recherches communes et de poser les problèmes aux Unions spécialisées par l'intermédiaire du représentant de l'UGGI à la Commission mixte de l'ICSU ?

Le Conseil et le Comité exécutif sont invités à proposer la solution qui leur semblera la plus appropriée. »

Prof. Bullen is grateful for discussion on this document. There is also the question of where radioactivity must necessarily concern our Association.

Prof. Coulomb says it is impossible to separate radioactivity from geochronology.

Prof. Richter : The only undesirable thing would be if papers in radioactivity were to be given in separate meetings which conflict in time, so we could not attend.

Sir Harold Jeffreys reminds of the Commission of P.E.I., which met in Brussels and had a large number of very well attended meetings before the main Assembly. This was precisely why the central Committee did not like it. I think a radioactivity commission might encounter the same difficulty.

Prof. Bullen : I hope I am correct in putting up the view that aspects of radioactivity are important to us.

Dr. Walter : The radioactivity in the interior of the earth is natural, whereas the radioactivity in the sea and air is mainly artificial, and does not concern us.

Prof. Bullen : In the detailed report, the suggestions apply to both natural and artificial radioactivity.

Dr. Hodgson : If there are two distinct divisions of radioactivity, we do not have to tie down the workers to a single field.

Prof. Bullen : I.A.V., I.A.H., I.A.P.O., and I.A.M.A.P. are all involved in this document. The question is whether we should keep right out.

Prof. Rothé suggests having one representative from our Association in the mixed Commission.

The session is closed.

THIRD SESSION

THURSDAY, SEPTEMBER 5 (morning)

Program

9. — Scientific communications : Magnitude and Earthquake Energy.

1. — *B. Gutenberg :* Introduction.
2. — *E. Bisztriczány:* A New Method of Magnitude Determination.
3. — *D. Di Filippo* and *L. Marcelli :* La « magnitudo unificata » per i terremoti a profondità normale, e la magnitudo di terremoti profondi per la stazione sismica di Roma.
4. — *M. Båth :* The Energies of Seismic Body Waves and Surface Waves.
5. — *N. V. Shebalin :* Correlation between Magnitude and Intensity of Earthquakes ; Asthenosphere.
6. — *V. I. Bune :* Experience in using Energy Characteristics in the Study of Tadjikistan Seismicity.
7. — *S. L. Solovyov :* Energy and Magnitude of Earthquakes.
8. — *B. F. Howell, Jr. :* Energy represented by Seismic Waves from Small Blasts.
9. — *C. Tsuboi :* Seismicity-Magnitude-Energy Relations for Earthquakes in and near Japan.
10. — *D. Tocher :* Earthquake Energy and Ground Breakage.
11. — *P. Byerly :* Energy of Earthquakes calculated from Geodetic Observations.
12. — *V. Kárnik, J. Vaněk,* and *A. Zátopek :* Contribution au problème des magnitudes unifiées.

This symposium has been organized by *Prof. Gutenberg.* The session is opened at 09.00 a.m. with Prof. Gutenberg in the chair.

9. Scientific communications : Magnitude and Earthquake Energy

1. — *Prof. Gutenberg* gives his Introduction.

Development of the magnitude scale and the calculation of earthquake energy on the basis of magnitude determination is summarized. Replacement of the magnitude scales by an internationally defined energy scale should be discussed during the symposium.

Prof. Gutenberg demonstrates relations between different magnitudes as well as between magnitude and energy. For details see B. Gutenberg and C. F. Richter : Magnitude and Energy of Earthquakes, *Annali di Geofisica,* Vol. IX, No. 1, pp. 1-15, 7 Figs, 1956, and B. Gutenberg : The Energy of Earthquakes, *Quart. Journ. Geol. Soc. London,* Vol. 112, pp. 1-14, 5 Figs, August, 1956.

2. — *Prof. Egyed* presents a paper by *E. Bisztriczány :* A New Method of Magnitude Determination.

The method utilizes the duration of the surface waves for magnitude determinations. The main interest lies in the fact that a parameter, involving this duration, is independent of distance within the interval 4 to 160 degrees. Besides the records of the Wiechert pendulum at Budapest ($V \backsim 200$, $\varepsilon \backsim 5$, $T_0 \backsim 10$ sec. mass $\backsim 1000$ kg) those of the Wiechert pendulum of Prague and the Galitzin instruments of Warsaw were used. The results seem to indicate that the method is of general applicability, independently of the kind of pendulum used. The data from the other stations were running parallel with the Budapest straight line. However, there is a slight dependence of the duration of the surface waves in the case of short-period instruments.

The complete text will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Prof. Press : The duration of the surface waves depends on their dispersion, which is very different along oceanic and continental paths. Has it been attempted to differ between oceanic and continental paths ?

Prof. Egyed : Such difference has not been made. The method seems to be applicable to deep-focus earthquakes as well.

Prof. Tsuboi : Taking into account that the magnitude data are plotted against log *t*, where *t* is the duration of the surface waves, expressed in minutes, up to the observed end of the seismogram, it is evident that for the near earthquakes the determination of the end must be made with greater accuracy and this is possible. For the greater earthquakes, however, the determination of the end does not require the same accuracy.

Prof. Gutenberg : This is an empirical result, which varies with instrument. It has the advantage that the duration is not needed to a high accuracy, because log *t* changes slowly.

Dr. Båth : We have been running parallel records of an old Wiechert and modern instruments. The new instruments often record surface waves several hours longer than the old instrument. The constants in the equation must therefore be determined for each instrument separately. — What is the standard deviation of a single observation ?

Prof. Egyed : Standard deviation is 0.34.

Prof. Richter : Arbitrariness due to choice of instrument in assigning a time to F may be removed by defining F as the time when the ground amplitude decreases below a specified level in microns. Especially in great earthquakes the true F may be lost in W2, or in the motion of large aftershocks.

3. — The paper by *D. Di Filippo* and *L. Marcelli :* La « magnitudo unificata » per i terremoti a profondità normale, e la magnitudo di terremoti profondi per la stazione sismica di Roma, is read only in title in the authors' absence.

Allo scopo di adeguarci agli sviluppi più recenti che il concetto di « magnitudo » dei terremoti ha avuto in questi ultimi anni abbiamo effettuato anche noi un aggiornamento sui rilievi fatti per il passato.

Com'è noto, la magnitudo dei sismi veniva data tramite formule che tenevano conto delle ampiezze delle onde superficiali orizzontali (limitatamente ad un periodo oscillante in un piccolo intorno di 20 s).

C'è inoltre, com'è ovvio, una stretta dipendenza con la distanza epicentrale. Alcuni termini numerici, caratteristici delle singole stazione, differenziano le formule tra loro.

Successivamente Gutenberg ha stabilito delle relazioni che tengono conto anche degli altri tipi di onde (P, PP ed S) le quali entrano nelle formule con i loro periodi e le loro ampiezze.

Una equazione lineare consente il passaggio dalla magnitudo calcolata con le onde superficiali a quella calcolata con le onde spaziali: questa equazione è per Pasadena

$$(\alpha)\quad m_B = 0.63\ M_S + 2{,}5 = M_S - 0{,}37\ (M_S - 6{,}76)$$

Dai rilievi diretti delle onde spaziali, la m_B è calcolata con la formula

$$(\beta)\left\{\begin{array}{l} m = \log \frac{u}{T} + Q + s \text{ (orizzontale) oppure} \\ m = \log \frac{w}{T} + Q + s \text{ (verticale)} \end{array}\right.$$

essendo u la risultante delle ampiezze orizzontali, w l'ampiezza verticale, T i corrispondenti periodi, Q i valori dati da Gutenberg e Richter mediante una serie di grafici, ed s una costante che dipende dalla stazione.

Per poter giungere anche noi ad una relazione tra la magnitudo calcolata con le onde superficiali e quella calcolata con le spaziali, abbiamo effettuato lo spoglio di 2 anni di registrazioni (1949-1950) ottenute presso la stazione sismica di Roma con apparecchi Galitzin I.N.G. e Galitzin-Wilip. Rilevate dove era possibile (e limitatamente ai terremoti di profondità normale) le ampiezze e i periodi delle P (orizzontali e verticali) delle PP (orizzontali e verticali) delle S (orizzontali) et delle M (con periodi 20 s), abbiamo calcolato per ogni terremoto le 6 magnitudo, servendoci per le onde spaziali delle formule di Gutenberg e Richter e adoperando per le Q le loro stesse tabelle, omettendo la costante di stazione che fa parte di un calcolo a parte.

Nel servirci delle onde superficiali abbiamo usato la nostra formula

$$(\gamma)\quad M = \log A + 1{,}526 \log \triangle + 2{,}439$$

Calcolate separatamente (con il metodo dei minimi quadrati) le formule che legano le $M(P_H)$, $M(P_Z)$, $M(PP_H)$, $M(PP_Z)$, $M(S_H)$ con la M rilevata dalla (γ), si trovano dei coefficienti confrontabili con quelli che Båth (Uppsala) ha trovato in un suo recente lavoro.

Conglobando inoltre i risultati parziali in un risultato generale, abbiamo ottenuto la formula seguente, confrontabile con la (α) di Gutenberg-Richter

$$(\delta)\quad m = 0{,}474\ M_S + 3{,}590 = M_S - 0.526\ (M_S - 6{,}822)$$

Messe in grafico le due equazioni (α) et (δ), si vede che esse coincidono praticamente in un intorno di $M_S = 7$ differenziandosi a destra e sinistra per valori simmetricamente opposti.

Della (δ) ci siamo valsi per determinare, di ciascun terremoto, la magnitudo unificata, mediando i valori calcolati direttamente delle onde spaziali, con quello calcolato applicando la (δ).

Un confronto tra le «magnitudo unificate» cosi ottenute e le corrispondenti magnitudo calcolate da Pasadena, permette la determinazione di un coefficiente per la stazione sismica di Roma, che consentirà, ci auguriamo, una uniformità di risultati almeno con l'America, poiché Pasadena è stata da noi assunta come punto di riferimento sia per la priorità del concetto di magnitudo che per l'autorità degli autori che a tali studi hanno dedicato la loro attenzione.

La II parte del lavoro è riserbata ad uno studio sui terremoti profondi. Per questi, esclusi dalla precedente trattazione, viene ricercata una funzione (ovviamente non lienare) che leghi la magnitudo calcolata con le onde spaziali, con l'ampiezza delle onde superficiali di periodo interno a 20 s.

The complete text will appear in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

See also *Annali di Geofisica,* Rome, Vol. X, No. 3-4, pp. 247-261, 7 Figs, 1957.

4.— *Dr. Båth* presents his paper on The Energies of Seismic Body Waves and Surface Waves.

Energy computations by means of body waves and surface waves for a number of shallow-focus earthquakes have given the following results (E = total seismic energy, E_{LR} = energy of Rayleigh waves, E_P = energy of P waves. E_S = energy of S waves, M_S = magnitude computed from amplitudes of surface waves).

1. The energy ratio E/E_{LR} decreases with increasing magnitude according to the formula

$$\log (E/E_{LR}) = 5.34 - 0.56\ M_S$$

This is explained by the influence of the linear dimensions of the source on the development of surface waves.

2. The following energy formula is deduced

$$\log E = 12.24 + 1.44\ M_S$$

in very good agreement with Gutenberg and Richter's latest results, obtained by completely different methods and different material.

3. The energy ratio $E_S/E_P = 1.5 \pm 0.4$ is independent of magnitude and of epicentral distance.

4. The extinction is very strong for the body waves and it may account for a factor of approx. 20 in the total energy. The extinction is mainly due to scattering within the crust in the focal region, increases with decreasing wave length, and is larger for transverse than for longitudinal waves. The usually assumed extinction along the total wave path in the mantle amounts to approx. ten to fifteen percent of the crustal extinction. The large extinction of the high frequencies in the focal region constitutes the most serious difficulty in energy determinations from body waves.

The complete text of this paper is published in the *Contributions in Geophysics,* Vol 1. pp. 1-16, 1 Fig., Pergamon Press, 1958.

Prof. Tsuboi: What is the value of M_S corresponding to your unified magnitude ?

Dr. Båth : The relation between M_S and m is

$$m = M_S - 0.37 \ (M_S - 6.76)$$

according to Gutenberg and Richter. Very similar formulas have been derived by myself (*Publ. Bur. Centr. Séism. Int., Série A, Trav. Sci., Fasc. 19,* pp. 5-93).

Dr. Lapwood asks why x = 2 is chosen for $M_S = 9$.

Dr. Båth : This is the weakest point in the argument. x must be > 1. Roughly we say that one half of the energy goes upwards and produces surface waves and what goes down is body waves, i.e. x = 2, even for the largest earthquakes. For smaller earthquakes x is larger according to the formula derived in the paper.

Prof. Gutenberg : Dr. Båth's paper strengthens the case for using E instead of M.

5.— *Mrs. Dr. Kondorskaya* presents the paper by *N. V. Shebalin:* Correlation between Magnitude and Intensity of Earthquakes ; Asthenosphere.

1. The influence of discontinuities on a part of the total flux of seismic energy emitting vertically upwards out of the earthquake focus is not significant. In particular, if the focus is under or over a certain discontinuity, the intensity in the epicentre should practically remain invariable. If it is accompanied by a drastic change of the relative amplitudes of surface waves, the latter can be revealed by correlating the earthquake magnitude and intensity.

2. Data on magnitude *M,* intensity *I* and focal depth *h* were obtained for 225 earthquakes with the focal depths from 3—5 to 640 km, magnitude — from 3.3 to 8.3 and intensity — from 3 to 11—12 grades. The magnitude was determined by the method of surface waves. In determining *M* for deep-focus earthquakes, the observed amplitudes of irregular surface waves characteristic of deep-focus earthquakes were used. Corrections for focal depth were not used. The focal depth was determined by the phases *pP* and *sS.* The focal depths within the Earth's crust were determined by the phase *sP.*

3. As a result of interpreting the observations, the following equation linking intensity *I* and magnitude *M* has been received :

$$1.5\,M - I = \delta(h),$$

where $\delta(h)$ is a parameter depending on focal depth.

4. With increasing focal depth from 5 to 80—100 km the value $\delta(h)$ changes from — 1 to + 4, which means that intensity decreases with the focal depth much more rapidly than the amplitudes of surface waves. For these depths we get

$$\delta(h) = -3.0 + 3.5 \lg h \text{ and } I = 1.5\,M - 3.5 \lg h + 3.0.$$

With a further increase of the focal depth the value $\delta(h)$ drastically decreases approximately by 2.5 units after which it goes up again ; for depths from 80—100 to 640 km it is expressed by the following equation :

$$I = 1.5\,M - 3.4 \lg h + 5.4.$$

A rapid increase of $\delta(h)$ can be explained only by an essential reduction of the surface wave amplitudes during the passage of the focus through a certain discontinuity.

5. The same effect should be produced by a layer with a lower velocity (asthenosphere) so far as a part of the energy flux, forming the surface waves in a vast zone around the epicentre, goes from below towards the upper boundary of asthenosphere at overlimited angles and is to be screened. Thereby there are grounds for identifying the boundary of a rapid decrease of $\delta(h)$ and the upper boundary of asthenosphere.

6. Within the limits of separate zones, a jump of $\delta(h)$ is made with a change of the focal depth by 10 or 15 km only. This testifies to a drastic increase of the velocity on the upper boundary of asthenosphere. The following data have been obtained on the depth of this boundary: Kamchatka — Japan — ca 80 km, Pamir — Hindu-Kush — ca 80 km, the South-American Andes — ca 65 km, the Caucasus — ca 55 km, the Carpathian Mts — ca 100 km, the Aegean Sea — Crete ca 90 km.

7. The criterium of a constant change of intensity during the passage of the focus through the discontinuity permits to conclude from the correlation of intensity and magnitude determined by body waves, that the curves $f\ (\Delta,\ h)$ by B. Gutenberg serving to find magnitude M of deep-focus earthquakes by body waves contain a regular error of the order of 0.7 beginning from the depth ca 80 km.

The complete text of this paper by N. V. Shebalin will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Prof. Gutenberg : We do not use magnitude determination for deep-focus earthquakes from surface waves any more. That shows part of the trouble. Also there is the effect of the continental crust.

Prof. Richter compliments the reader on her clear presentation in English, and says this is a most significant paper. We are assigning M for deep-focus earthquakes from body waves but ignore loss of energy.

6. — *Mrs. Dr. Kondorskaya* presents the paper by *V. I. Bune :* Experience in using Energy Characteristics in the Study of Tadjikistan Seismicity.

1. The methods of classifying earthquakes in Tadjikistan in their energy by instrumental data are based on the estimates of earthquake energy by the Galitzin method and of the correlation of the energy value with the determinations of M and of maximum distance in registration.

2. Epicentres of strong earthquakes in Tadjikistan are, mainly, distributed regularly. The zone of strong earthquakes stretches nearly in a latitudinal direction along the border of the Southern Tien-Shan and along the southern spurs of the Gissar and Alai ridges.

Especially active is an area southwards of the joint of the Gissar, Zeravshan and Alai ridges. The zone of intensive activity also embraces the Peter I ridge.

Further, southwards of the Pamirs border (Darvaza ridge) seismic activity drastically decreases.

A zone of strong deep-focus earthquakes stretches southwestwards of Murgab to Horog and further to the south-west, on the territory of Afghanistan.

The greater part of strong deep-focus earthquakes occur southwest of Horog, in the northern spurs of Hindu-Kush.

3. Zones of the most numerous weak earthquakes which can be observed in Tadjikistan within a short period of time, mostly coincide with those of strong earthquakes.

4. A comparative estimate of seismic activity in various regions can be made by determining the seismicity coefficient after Toperczer, by building graphs of frequency and energy of earthquakes after Gutenberg (seismicity graphs) as well as by building graphs of seismic energy with respect to time.

5. A comparative analysis of the seismicity of three regions in Tadjikistan (the Hait, Tovil-Dora and Stalinabad regions) and the use of the estimate of earthquake energy enables us to characterize seismicity of different regions in some figures and diagrams.

These data are a vivid evidence to the high activity of the Hait region as compared with other regions of Tadjikistan.

6. The analysis of seismic activity of narrower epicentral zones requires a much higher accuracy in determining the epicentre coordinates. Such an accuracy (± 3 km in the average) may be achieved by expeditionary work at temporary stations.

7.— *Mrs. Dr. Kondorskaya* presents the paper by *S. L. Solovyov:* Energy and Magnitude of Earthquakes.

1. At present the earthquake energy is usually thought of as a summarized energy of its elastic waves.

In most cases, it is probably sufficient to take account of only body wave energy because the energy of surface waves is comparable with that energy only for very strong earthquakes. However, the existing formulae for estimating the energies of surface waves (H. Jeffreys, S. I. Kosenko) contradict some empirical facts and need to be checked up.

The energy of *S* waves is the main component in the earthquake energy. As a rule, it is several times larger than for *P* waves, but the exact ratio of these quantities varies from one earthquake to another. The simplest formula for estimating the energy of *S* waves is the one for a spherical and symmetrical source in an infinite space, which was first used by B. B. Galitzin. It is best applicable to the wave *SH* ($\Delta \leqq 200$ km). At greater distances ($\Delta > 20^{\circ}$) the Zoeppritz-Wiechert-Gutenberg formula may be used. The functions necessary for its application can be found, say, by differentiating the travel-time curve. The coincidence of the energy estimates has been shown by the two formulae.

The asymmetry of energy emission is taken into account by means of corresponding formulae.

2. Since 1953 the earthquake magnitude scale was used in the USSR. The applied type of M-scale was based on surface waves. The magnitude of a shallow earthquake is thought of as the magnitude of the velocity field in surface waves. The corresponding calibrating curve ($3^\circ < \Delta < 100^\circ$) is built on the basis of the Gutenberg curve and independently. It is shown that the magnitude determined by a ground displacement in the surface waves differs little from that determined by the velocity so far as the surface wave period depends but slightly on the earthquake magnitude.

It was observed that for the Pacific foci ground displacements on coastal stations were twice or thrice less than those on continental stations with the same epicentral distances.

3. A study was made on the relation between energy and magnitude. The work was conducted separately for weak and strong earthquakes of the Far East and Central Asia. The fact established in the above paragraph leads to a difference between corresponding equations for various regions. A mean equation for Central Asia ($\lg E \approx 11.5 + 1.5\ M$) approximately coincides with Gutenberg and Richter's results for California.

It follows from these equations that with the growth of the total earthquake energy the relative share of the surface wave energy increases.

Investigations have been made on the regime of energy in some of the seismically active regions of the USSR.

The complete text of the paper by S. L. Solovyov will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

8.— Prof. B. F. Howell, Jr., presents his paper on Energy represented by Seismic Waves from Small Blasts.

In attempting to calculate the energy of a disturbance resulting in an observed train of seismic waves the following must be known or assumed: 1. fraction of total energy represented by movement (usually in form of velocity) of the ground; 2. directional pattern of energy radiation from source and as a result of geologic structure; 3. velocity and direction of transmission of the energy at recording stations; 4. rate of attenuation with distance; 5. density of rock underlying the recording station; and 6. sensitivity of recording instruments throughout the band of frequencies involved in the seismic pulse. The influence of uncertainties in each of these areas is examined and examples given of the range of errors expectable in the case of disturbances caused by very small dynamite blasts. It is concluded that energy calculations based on seismogram amplitudes can not be expected to give more than an order of magnitude figure for the causative energy even under the best of circumstances, but that with proper care to evaluate the various error-causing factors, comparative measures may be capable of greater accuracy.

The complete paper will appear in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20* (with 4 figures). Reference is also made to the following two papers : B. F. Howell, Jr., and E. K. Kaukonen : Attenuation of Seismic Waves near an Explosion, *Bull. Seism. Soc. America,* Vol. 44, No. 3, pp. 481-491, 9 Figs, July, 1954.

B. F. Howell, Jr., and D. Budenstein : Energy Distribution in Explosion-Generated Seismic Pulses, *Geophysics,* Vol. XX, No. 1, pp. 33-52, 12 Figs, January, 1955.

Dr. Båth asks if differences in attenuation has been found between P and S waves.

Prof. Howell replies that observations were made only of P waves.

Prof. Lomnitz : Least absorption occurs around 50 cycles/sec. Does this apply to all depths ?

Prof. Howell: This was an impact experiment giving a very short pulse.

Prof. Dix : Have you assumed same efficiency at all depths ?

Prof. Howell : Efficiency increases with depth. We had an increase all the way down to the first really solid limestone at 100 feet.

Dr. Stoneley : You have an exponential term and x^a in your formula. You use $a = -2$. Have you any evidence governing the value of a ?

Prof. Howell : You can use $E = E_0 \ x^A$. A varies rapidly with distance and is different for surface and body waves.

9. — *Prof. Tsuboi* presents his paper on Seismicitiy-Magnitude-Energy Relations for Earthquakes in and near Japan.

The magnitude M of an earthquake which occurs in or near Japan and which is observed at Japanese seismological stations has been found to be given by the relation

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

where A is the maximum ground amplitude (in micron) due to the earthquake observed at the distance Δ (in km).

By means of this formula the magnitudes of 1025 shallow earthquakes which occurred in and near Japan from 1931 through 1955 and which were felt beyond 200 km from the respective origins have been determined. The mean annual number N of earthquakes according to the magnitude has been found to be expressed by

$$\log N = -1.08 + 0.72 \ (8 - M)$$

for $\Delta M = 0.1$.

The mean rate of energy release by earthquakes in and near Japan has been estimated to be 1.5×10^{8} ergs/cm^2 year or 0.1×10^{-6} cal/cm^2 sec.

As a whole, Japanese area is contributing well over 10 % to the total seismicity of the world.

The area A (in cm^2) in which aftershocks of a large earthquake occur (aftershock area) has been found by T. Utsu to be related to the magnitude of the main shock as follows :

$$\log A = M + 6$$

The present author has long been of the opinion that the energy of a large earthquake is stored in a volume approximately given by a . 3a . 3a just prior to its occurrence (a = extension in depth). In this volume (earthquake volume), the stress density ($\frac{1}{2}ex^2$; e = elastic constant ; x = ultimate strain) is very roughly uniform and there are also reasons to believe that this density does not depend on the magnitude of the earthquake.

If aftershocks of a large earthquake occur in the volume in which the energy of the main earthquake has been stored up (that is within the earthquake volume) and if the aftershock area is the horizontal projection of the volume, then

$$E = (\frac{1}{2} ex^2)\ 9a^3$$

$$\log E = \log (\frac{9}{2} ex^2) + 3 \log a$$

$$= \log (\frac{9}{2} ex^2) + 1.5 \log A - 3 \log 3.$$

On the other hand, according to B. Gutenberg and C. F. Richter,

$$\log E = 11.8 + 1.5 M$$

Therefore

$$11.8 + 1.5 M = \log (\frac{9}{2} ex^2) + 1.5 \log A - 3 \log 3$$

or

$$\log A = M + 7.86 - \frac{1}{1.5} \log (\frac{9}{2} ex^2) + 2 \log 3$$

With $e = 5 \times 10^{11}$, $x \times 10^{-4}$, this reduces itself into

$$\log A = M + 5.9$$

which is almost exactly the same as the relation found by Utsu.

This paper is a summary of the following three papers by Prof. Tsuboi :

Magnitude-Frequency Relation for Earthquakes in and near Japan, *Journ. Phys. Earth,* Vol. 1, pp. 47-54, 4 Figs, Tokyo, 1952.

Earthquake Energy, Earthquake Volume, Aftershock Area, and Strength of the Earth's Crust, *Journ. Phys. Earth,* Vol. 4, pp. 63-66, Tokyo, 1956.

Energy Accounts of Earthquakes in and near Japan, *Journ. Phys. Earth,* Vol. 5, pp. 1-7, 2 Figs, Tokyo, 1957.

Prof. Benioff : Prof. Tsuboi's assumption that the length and width of the strained area is 3 times the depth was derived from gravity data and would refer to earthquakes having vertical slip only. Transcurrent fault earthquakes would not follow this rule.

Prof. Tsuboi says, in reply to a question by *Dr. De Bremaecker,* that he plotted Σ log NE versus M and found that small shocks contribute very little to the total energy.

Dr. Lapwood asks why $x = 10^{-4}$ was chosen for the strain.

Prof. Tsuboi : This was obtained from the vertical deformation of the earth's crust, comparing the geodetic observations before and after the shock.

10.— Dr. D. Tocher presents his paper on Earthquake Energy and Ground Breakage.

Seismographic data of sufficient quality for estimating the Richter magnitudes of earthquakes centered in northern California and Nevada begin with the San Francisco Earthquake of 1906. Since then, every shock of magnitude over 6-½ in the region has been accompanied by some degree of fault breakage at the surface of the earth. The smallest shock for which such effects have been observed was one of magnitude 5-¾.

Correlation of the length of observed breakage with earthquake magnitude suggests provisionally that the initially strained rock which contributes energy to a large, shallow earthquake in this region is a slab of the earth's crust bounded above by the earth's surface and below by a zone in which the rock can deform plastically at a rate high enough to keep pace with the elastic deformation of the overlying slab. While no direct seismographic evidence is available to determine the level of the bottom of the zone of strained rock, indirect evidence suggests that it is no deeper than the Mohorovičić discontinuity (which is about 30 kilometers deep in northern California), and that it may be considerably shallower.

The complete text is published in the *Bulletin of the Seismological Society of America,* Vol. 48 No. 2, pp. 147-153, 3 Figs, April, 1958.

Dr. Båth asks for explanation how the energy formula was derived.

Dr. Tocher says that P, SV, SH, and surface waves were used by integration of records.

Prof. Gutenberg says he has doubt of the value of integration of surface waves without knowing the proper exponential term with depth.

Dr. Tocher says he tried to use appropriate surface wave theory.

Prof. Benioff remarks that the focus is the point where the ratio of strength : stress is a minimum.

Prof. Tsuboi : Many use the volume in which the energy is stored. Let us use « earthquake volume ».

Prof. Benioff says he has been using « strained volume », whereas *Sir Harold Jeffreys* prefers « earthquake volume », because it can be defined as we please, and *Prof. Howell* prefers « source volume ».

11.— Prof. P. Byerly reads his paper on Energy of Earthquakes Calculated from Geodetic Observations.

Three earthquakes of the western United States have been accompanied by large surface fault displacements. They were all in a region which had been well surveyed geodetically before and after the faulting.

The strain displacements may be fitted to a formula. Integration gives the strain energy after a number of assumptions have been made. In general the energies so obtained are smaller, instead of larger, than those obtained from magnitude formulae.

The complete text of this paper is published together with J. DeNoyer in the *Contributions in Geophysics,* Vol. 1, pp. 17-35, 10 Figs, Pergamon Press, 1958. See also *Trans. Am. Geophys. Union,* Vol. 37, No-3, June, 1956, p. 338 (abstract by P. Byerly & J. DeNoyer).

Prof. Benioff : These calculations assume that the fault is lubricated in the under surface.

Prof. Byerly : Knopoff's theory assumes finite stress there with some energy below. We assumed lubrication.

12. — *Prof. Gutenberg* reads the following summary of the paper by *V. Kárník, J. Vaněk,* and *A. Zátopek :* To the Problem of Unification of Earthquake Magnitude Scales (Contribution au problème des magnitudes unifiées).

At the station of Praha earthquake magnitudes are determined from calculated ground amplitudes of surface and body waves (LH, MH and PH, PV, PPH, SH respectively) in the range of distances from 1° to 160° for shallow earthquakes.

Recently the methods were unified so that the magnitudes M of Praha are uniformly determined by aid of a fundamental relation

$$M = \log (A/T) + \beta (\Delta, T) + \delta\Sigma M,$$

where A is the ground amplitude and T the corresponding period of the component in question (horizontal or vertical), $\beta(\Delta, T)$ denotes a calibrating function of epicentral distance Δ and period T for $M = O$, given in form of tables or graphs for each wave and component. The sum $\Sigma\delta M$ implies the corrections, of which only that for the station constant (denoted by δM^s) and that for the depth (δM^h, if surface waves are considered) are included in the magnitude values published in the bulletins of Praha. The corrections for the focal depth were empirically determined for surface waves and are still subject of a statistical study for body waves. The further corrections are the regional correction δM^r and an individual correction D, respecting the irregularities not considered in the above corrections. The present authors believe the last two corrections to be very important for the study of the structure of the earth's crust.

Relations between the magnitudes determined from surface and body waves (M_{MH} and M_{PH}, M_{PV}, M_{PPH}, M_{SH} respectively) for Praha are very similar to those found by Båth for Uppsala and Kiruna.

The final formula, representing the dependence of a set of 465 values of magnitudes as determined from all body waves considered, and the corresponding system of magnitudes from surface waves, results in the form

$$M_{MH} - m_{MH} = 0.389 \, (M_{MH} - 6.98).$$

This reduction, giving for the « equivalent » magnitude m_{MH} of M_{MH} numerical values, which differ in the range $5 \leq M < 9$ from those by Gutenberg at most by 0.13 units of magnitude, may be used with sufficient accuracy for the calculation of the « unified magnitudes ». These are in Praha calculated according to the definition of Gutenberg as a weighted mean from the body wave magnitudes and the reduced value of magnitude for surface waves. Their coincidence with the values of Pasadena is surprisingly good. One sees that the unified magnitudes will certainly be of a great importance for the investigations of seismicity, for energy considerations etc.

For more detailed study of certain regions and for the investigations of individual cases and special problems the unified magnitudes will not be so convenient as they are neglecting the particularities of individual waves. Therefore the present authors recommend that the magnitudes be determined if possible for all kinds of waves mentioned above by a uniform procedure corresponding to the first of above equations at all stations and that the corresponding magnitudes be given in bulletins in addition to the value of the unified magnitude.

The complete text of the paper by V. Kárník, J. Vaněk, and A. Zátopek will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Prof. Gutenberg : I agree with this paper. I should like all stations to give the maximum amplitude within P, PP, and S (the largest amplitude occurring within 10-15 sec after the first onset).

The final discussion on the whole problem is quite brief for time reasons.

Prof. Gutenberg : We must decide which quantities we publish in the future. I publish m and E. but we should get together on this. I dislike M, but it is still often given.

Dr. De Bremaecker : We calculate magnitudes from surface waves, and we find a standard deviation of ± 0.3 units. We think it is due to scatter.

Prof. Richter : The use of the original magnitude scale for local earthquakes is unavoidable, since its relation to magnitudes determined at great distances is not yet settled. For teleseisms, the choice between the scales m based on body waves and M based on surface waves is like that between the Fahrenheit and Celsius scales of temperature. Such choice should be based in convenience and experience, not on arbitrary *a priori* decisions.

The session is closed.

FOURTH SESSION

FRIDAY, SEPTEMBER 6 (morning)

Program

9.— Scientific communications : Crustal Structure of Continents and Ocean Basins.

- *13.— J. Cl. De Bremaecker* and *Ed. Berg :* Rayleigh Waves with Mixed Paths and Crustal Structure in Central Africa.
- *14.— B. K. Balavadze* and *G. K. Tvaltvadze :* Structure of the Earth's Crust in Georgia from Geophysical Evidence.
- *15.— L. S. Veytsman, I. P. Kosminskaya,* and *Y. V. Riznichenko :* New Evidence for the Structure of the Earth's Crust and Mountain Roots in Central Asia from Data on Seismic Depth Sounding.
- *16.— R. Stoneley* and *U. Hochstrasser :* The Propagation of Rayleigh Waves across Continents and the Ocean Floor.

17. — *M. Båth :* A Continental Channel Wave Guided by the Intermediate Layer in the Crust.

18. — *M. Båth :* A Revised Model for Continental Channel-Wave Propagation.

19. — *B. Gutenberg :* Crustal Structure in California.

20. — *H. Jeffreys :* Elastic Waves in a Continuously Stratified Medium.

This symposium has been organized by *Prof. Press*. The session is opened at 09.00 a.m. with Prof. Press in the chair.

9. Scientific communications : Crustal Structure of Continents and Ocean Basins

13. — After a short introduction by *Prof. Press, Dr. De Bremaecker* presents a paper by himself and *Ed. Berg :* Rayleigh Waves with Mixed Paths and Crustal Structure in Central Africa.

For distant earthquakes Rayleigh waves which have a mixed path, i.e. both continental and oceanic, generally show rapid variations in amplitudes. These are interference phenomena due to packets of waves with slightly different periods arriving from different azimuths. In each packet the periods vary continuously but each destructive interference corresponds to a sudden change in period and in azimuth. The dispersion curves show a distinct « en échelon » pattern which corresponds to these phenomena.

Phase velocities between the three stations of the I.R.S.A.C., i.e. Lwiro, Uvira and Astrida forming a triangle astride the West African Rift Valley are examined with a view to determining the mean thickness of the crust in this area.

The complete paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. No 20.*

Dr. De Bremaecker explains his experience of the method in replies to questions by *Father Ingram, Dr. Oliver,* and other delegates: Usually our present separation between the stations is adequate. With higher paper speeds the separation could be diminished. — The wave lengths are around 60 km. — A group of stations cannot preferably be used to eliminate interference effects. You must have a triangle. Waves in different azimuths are confusing. — Only long-period records were used and they were not mixed with other records.

Prof. Press : In practice, one needs simple paths (oceanic and simple entry to continent), if surface waves are to be used in deducing structures.

14. — *Dr. Riznichenko* presents the paper by *B. K. Balavadze* and *G. K. Tvaltvadze* on Structure of the Earth's Crust in Georgia from Geophysical Evidence.

1. To study the structure and physical properties of the layers composing the Earth's crust in Georgia, as well as the adjoining regions of the Caucasus, the Geophysical Institute (now Institute for Physics of the Earth) of the USSR Academy of Sciences (acad.

G. A. Gamburtsev; E. A. Koridalin) and the Institute of Geophysics of the Georgian SSR (B. K. Balavadze, G. K. Tvaltvadze) have made joint seismometrical and gravimetrical investigations.

Seismic investigations have been made in separate intermountain regions of the Caucasus and the Akhalkalaki Nagorie by methods of deep seismic sounding of the Earth's crust and by registering elastic waves from powerful industrial blasts.

Gravity observations were conducted with the help of gravimeters all over Georgia. The material was treated with the Bouguer reduction with account of the corrections due to the influence of topographical masses and deviations of the geoid from the spheroid.

A densitometric survey of the whole territory explored has also been made.

2. The results of the seismic investigations, aimed at revealing the nature of separate complexes composing the Earth's crust in the Kura depression in the Caucasus areas, follow:

a) a sedimentary layer with a thickness from 0 to 8 km and effective and mean velocities of P and S waves respectively:

$$V_p = 3.5\text{—}4.4 \text{ km per sec}; \quad V_s = 2.2\text{—}2.6 \text{ km per sec};$$

b) a granite layer divided into two parts: the upper 4—8 km thick with the following velocities:

$$V_p = 5.6 \text{ km per sec}; \quad V_s = 3.2 \text{ km per sec}$$

and the lower, 8—10 km thick with the velocities:

$$V_p = 6.0 \text{ km per sec}; \quad V_s = 3.4 \text{ km per sec};$$

c) a basalt layer 23—26 km thick with the velocities:

$$V_p = 6.7 \text{ km per sec}; \quad V_s = 4.0 \text{ km per sec}.$$

Thus, the thickness of the Earth's crust in the depression part of the Caucasus is of the order of 48—50 km.

The boundary velocities in the mantle substratum are:

$$V_{bP} = 7.9\text{—}8.1 \text{ km per sec}; \quad V_{bS} = 4.6\text{—}4.7 \text{ km per sec}.$$

Taking into account the peculiarities in the structure of the Earth's crust, a diagram of travel time curves for different focal depths has been drawn up by the following formulae:

for direct waves:

$$t_{kn} = \frac{h - \sum\limits_{1}^{k-1} H_i}{V_k \sin l_k} + \sum_{1}^{k-1} \frac{H_i}{V_i \sin l_i};$$

for head waves:

$$t_{kn} = \frac{\Delta}{V_n} + \frac{\sum\limits_{1}^{k} H_i - (h - H_k)}{V_k} \sin l_{kn} + \sum_{1}^{k-1} \frac{H_i}{V_i} \sin l_{in} + \sum_{k+1}^{n-1} \frac{2H_i}{V_i} \sin l_{in}.$$

With the focus under the Earth's crust:

$$t_{NN} = \int_{0}^{h-H} \frac{dz}{V_n^{\circ}\,(1+\beta z)\sqrt{1 \quad (1+\beta z)^2 \cos l_n}} + \sum_{1}^{N-1} \frac{H_i}{V_i \sin l_i}$$

3. Considering the gravity anomaly on the territory of Georgia mostly as the result of an influence of disturbing masses in the sedimentary layer and at the foundations of the granite and basalt layers, an attempt was made to solve quantitatively the inverse gravimetric problem by means of seismic, magnetic, geological and densitometrical data utilizing also some world data on the structure of the Earth's crust from geophysical works.

It is adopted that the mean density of sedimentary formations ranges from 1.9 to 2.75, while the densities of the granite, basalt and mantle layers are respectively equal to: 2.65; 2.85 and 3.40 gr per cm^3.

As a result of a complex interpretation of the above data, it was found that:

The thickness of the Earth's crust in Georgia ranges approximately from 40 to 67 km, whereas the greatest thickness of the crust (50—67 km) is supposed to be under the central part of the Great Caucasus and under the Akhalkalaki Nagorie, the least one — (40—45 km) under the Dzirula crystalline massive and Tsikhisdziri. Under the Kolkhida Lowland the thickness of the Earth's crust gradually decreases towards the Black Sea.

The approximate thickness range of the layers of the Earth's crust in Georgia along the analyzed profiles seems to be the following: for the sedimentary layer — from 0 to 8 km, granite layer—from 14 to 35, basalt layer—from 24 to 35 km. It should be noted here that due to an insignificant difference of density on the discontinuities of media of basalt-granite and granite-sedimentary layers these discontinuities are determined less confidently than that of the substratum-basalt media (the Mohorovičić surface).

The general character of changes in the regional gravity anomalies in Georgia is determined in mountain regions by a change mostly of the substratum surface which is a place of the greatest change in density and velocity of elastic waves, and in intermountain and foothill regions chiefly by a change in the surfaces of granite and substratum.

The complete paper by B. K. Balavadze and G. K. Tvaltvadze will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Prof. Birch : Could you show any evidence for the discontinuity between the granite and any other layer ?

Dr. Riznichenko: There are only seismic data.

Prof. Birch: Do you have your plot ? The division of layers is largely a matter of interpretation.

Dr. Riznichenko: The layers are investigated by reflections and refractions. In the complete paper all the data are included.

Prof. Birch: Have you had reflections in the deep part of the trough ?

Dr. Riznichenko: No — only outside. In some places we have reflections from 48 km depth. Refraction data from earthquakes were also used. There are other investigations by depth sounding in other parts of the Caucasus.

15. — *Dr. Riznichenko* presents the paper by *P. S. Veytsman, I. P. Kosminskaya,* and *Y. V. Riznichenko*: New Evidence for the Structure of the Earth's Crust and Mountain Roots in Central Asia from Data on Seismic Deep Sounding.

1. In the USSR as well as in other countries, seismic observations of elastic waves from industrial blasts were repeatedly used in continental investigations of the structure of the Earth's crust and the upper part of the Earth's mantle. Experience shows, however, that these methods often fail to provide the necessary accuracy and thoroughness of investigations.

2. In the Geophysical Institute of the USSR Academy of Sciences, now the Institute for Physics of the Earth, a new accurate method for investigating the Earth's crust has been developed under acad. G. A. Gamburtsev's guidance. This method of Seismic Deep Sounding (SDS, or in Russian GSZ) is similar to the modern methods of seismic prospecting. It was successfully used in different regions of Central Asia.

The development of the SDS method started as far back as 1938. The main investigations of the Earth's crust by this method were carried out in 1949—50 and later on. In the SDS method special, rather small shots are used and correlation principles of tracing seismic waves recorded by many-channel seismic stations applied.

3. In the SDS method head refracted waves are used, for the most part.

In this respect the SDS method is similar to the correlation method of refracted waves (CMRW, or in Russian KMPV), developed in the same institute under G. A. Gamburtsev's guidance, and now widely used in industry. The SDS method differs from the CMRW mainly in a lower frequency region (about 10 c. p. s.) and in the use of more sensitive apparatus. The range of the shot distances of the SDS method is much greater than that of prospecting and reaches hundreds of kilometres.

4. In the SDS method observations are made on longitudinal and non-longitudinal profiles as well as on separate profile crossings located in a certain area. In case of long profiles, observations were usually made on separate continuous segments. The length of these continuous segments as well as the intervals between them range from a few to dozens of kilometres. In addition to linear observation systems providing a « position » wave correlation, point systems with many-channel azimuthal installations, providing « azimuthal » wave correlation in one point have been used.

5. The high resolving power of the SDS method enables us to study the depth and shape of the main seismic discontinuities— the surfaces of the granite and basalt layers and the Mohorovičić discontinuity, and also to investigate deep faults in the Earth's crust connected with earthquake origins.

A comparison of the Earth's crustal sections obtained by the SDS method with gravimetric data makes it possible to identify regional gravity anomalies due to the masses of granite and basalt layers, and of the upper part of the mantle. Observation systems used in the SDS enable us to determine the values of the boundary velocities of P seismic waves along the main seismic discontinuities and, in some cases, the average vertical velocities in the crust.

6. In recent years the SDS method has been used for a study of the deep structure of the Earth's crust in the seismically most active mountain and foot-hill regions of Central Asia: the Northern and Southern Tien-Shan, the Pamirs and Turkmenia. The work was carried out in combination with geological investigations and a study of seismicity of the regions.

7. In the investigated regions of Central Asia a number of irregularities of the Earth's crustal structure have been found. In the transition zone from platform to mountain regions a considerable increase in the thickness of the Earth's crust ranging from 30 to 70 km was observed. A large variety of relations between the thickness of the granite and basalt layers was found. The relief of the basalt layer surface was in most regions considerably more complex than that of the Mohorovičić discontinuity.

In the Northern Tien-Shan, mountain ridges correspond to a rise of the basalt layer and an increase of its thickness in comparison with the depression regions.

The Mohorovičić discontinuity sinking somewhat under the mountain ridges forms the sloping mountain roots embracing large mountain systems, whereas in the basalt layer the surface relief is repeated to a great extent. The crustal thickness varies from 40 to 53 km, that of the granite layer from 8 to 17 km, that of the basalt layer from 23 to 45 km. A similar picture of non-concordant main seismic boundaries was also found in the Southern Tien-Shan (Alai) and Western Turkmenia (Kopet-Dag). A concordant location of the basalt layer surface and that of Mohorovičić was found in the Northern Pamirs where both surfaces sink down forming mountain roots, in Western Turkmenia (Bolshoi Balkhan ridge) where both surfaces rise, creating the so-called anti-roots under the mountains.

It should be noted that whereas in the Northern Tien-Shan mountain roots are due to an increase in the thickness of the basalt layer, in the Pamirs they are due to an increase in the thickness of the granite layer which in that region amounts to 45 km.

8. The mountain regions of Central Asia are characterized by large negative gravity anomalies from 200 to 450 milligals (Bouguer reduction).

A joint quantitative analysis of gravity and seismic data shows that gravity anomalies are mainly caused by the shape and depth of the Mohorovičić discontinuity. However, of great significance are also the shape and depth of the basalt layer surface. When non-concordant with the Mohorovičić discontinuity this surface seemingly compensates the gravity anomaly. Thus, different gravity anomalies may be observed in regions with an equal thickness of the Earth's crust which was the case in the regions investigated.

The complete text will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Dr. Riznichenko replies to a number of brief questions from various delegates, *Prof. Byerly, Father Gherzi, Prof. Press, Prof. Rothé,* and others : The space between the instruments was 200 meters. — Investigations were made as far east as 47° N, 80° E. — Shear waves were sometimes, but not always, observed and studied. — The magnification was several million. — In places where the crust is very deep, Pn was the first onset. — Good reflections were obtained near the critical angle, whereas vertical reflection experiments were unsuccessful.

16. — *Dr. Stoneley* presents the paper by himself and *U. Hochstrasser* on The Propagation of Rayleigh Waves across Continents and the Ocean Floor.

The numerical solution of the velocity equation for Rayleigh waves in a medium with a double surface layer gives reasonable agreement with the measurements of the dispersion of such surface waves in a continent. The values of the wave velocity may be used to calculate the amplitude at all depths : such a computation, made with an electronic computer, shows that the ratio of the vertical displacement to the horizontal displacement at the free surface nowhere transcends the value corresponding to a uniform solid, and reaches a minimum value of about 1.15 on the three continental models considered.

For Rayleigh waves crossing an ocean floor a realistic representation involves a three-layer problem, that is, two rocky surface-layers and a liquid layer. The wave velocity equation is found as an eleven-row determinant ; the dispersion curves corresponding to eight different assumed constitutions have been obtained by the help of the SEAC computer at the National Bureau of Standards, Washington, D.C., and the results have been applied to observations of Rayleigh waves over oceanic paths.

This communication is based on the following papers :

R. Stoneley : Rayleigh Waves in a Medium with Two Surface Layers, First Paper, *Mon. Not. Roy. Astr. Soc., Geophys. Suppl.,* London, Vol. 6, pp. 610-615, 1954.
Second Paper, *Mon. Not. Roy. Astr. Soc., Geophys. Suppl.,* London, Vol. 7, pp. 71-75, 1955.

R. Stoneley and U. Hochstrasser : The Attenuation of Rayleigh Waves with Depth in a Medium with Two Surface Layers, *Mon. Not. Roy. Astr. Soc., Geophys. Suppl.,* London, Vol. 7, pp. 279-288, 1957.

R. Stoneley : The Transmission of Rayleigh Waves across an Ocean Floor with Two Surface Layers,
Part. I, *Bull. Seism. Soc. Amer.,* Vol. 47, pp. 7-12, 1957.
Part II will be submitted as a paper jointly with U. Hochstrasser to *Bull. Seism. Soc. Amer.*

Prof. Bullen: Can you find the total thickness of the outer layers from a dispersion curve? What is the uncertainty?

Dr. Stoneley: By assuming different models we found for Euroasia between 35 and 45 km. Of course, isostatic results indicate great local variations and the results can only be an average.

Dr. Båth: Do you always assume zero velocity gradient below the Mohorovičić discontinuity?

Dr. Stoneley: I have been thinking of that. It could be very important for the long waves.

Dr. Willmore: Have you considered the effect of curvature?

Dr. Stoneley: No, but I have it in mind. It was solved by A.E.H. Love for a uniform earth. — In reply to a question of differences between Western and Eastern Atlantic, Dr. Stoneley refers to works by Hill and Ewing.

17. — *Dr. Båth* presents his paper on A Continental Channel Wave Guided by the Intermediate Layer in the Crust.

A study has been made of a new channel wave, denoted Li, using a total of 83 observations from the seismic records of Swedish stations, mainly from earthquakes at normal depth. Li resembles the Lg waves in several respects: it propagates only through continental structures, it has a similar particle motion, i.e. mainly transverse horizontal, and only slightly larger period. But Li has a higher velocity, 3.79 ± 0.07 km/sec, and it is believed to propagate in the intermediate layer in the crust in a way similar to the propagation of the Lg waves in the granitic layer. Li is identical with S* in records of near-by earthquakes in the same way as Lg2 is identical with Sg. Li usually exhibits no clear dispersion.

The complete paper has been published in *Geofisica pura e applicata,* Vol. 38, pp. 19-31, 5 Figs, Milano, 1957.

The discussion is postponed until after the next paper, which is closely related to this paper.

18. — *Dr. Båth* presents his paper on A Revised Model for Continental Channel-Wave Propagation.

Various models for continental channel-wave propagation, including a « classical » model, Gutenberg's model, and an earlier model of the present author, are discussed. As a result, mainly based upon comparisons of calculated and observed energy ratios of channel waves and body waves, a revised model is proposed. In this model Gutenberg's velocity distribution in the continental crust with one granitic and one intermediate low-velocity layer has been adopted. Lg1 and Lg2 travel in the granitic layer and Li in the intermediate layer. Lg1 propagates by successive reflections against the earth's surface, Lg2 propagates by successive reflections against the upper side of the Conrad discontinuity or by successive reflections both at the earth's surface and at the Conrad discontinuity, and Li propagates by successive reflections from the upper side of the Mohorovičić discontinuity.

This paper is a part of a larger paper by M. Båth: Some Consequences of the Existence of Low-Velocity Layers, *Annali di Geofisica,* Vol. 9, No. 4, pp. 411-450, 8 Figs, Rome. 1956.

Dr. Tocher: Your proposed mechanism for transmission of your Li wave involves observations made at some distance from the axis of the low-velocity channel. From energy considerations, would it not be as well to assume that the transmission is that of Stoneley waves at an interface within the crust, where you again would be observing at the same distance away from the axis of the transmitted energy path?

Dr. Båth : The earth's surface is within one wavelength or less from the channels. The interpretation in terms of Stoneley waves is certainly a possibility, but the interpretation of Li was made in analogy with the interpretation of Lg1, which could not easily be taken as a Stoneley wave. Furthermore, the Gutenberg velocity-depth model, based on other data than channel waves, would require a wave propagation for Li, as I have pictured it.

Dr. De Bremaecker : At Lwiro we observed large Lg waves from the Southern Turkey shocks on April 24-25, 1957, but none from the Northern Turkey shock on May 26, 1957. The waves followed the same path. The cause may be differences in focal mechanism.

Dr. Båth : I agree that quite different channel waves can be recorded from different earthquakes, even if the paths are nearly the same. The Aegean region is structurally very complex, which may explain the different behaviour.

Prof. Press: It might later be possible to fit all channel waves to higher-mode Love and Rayleigh waves.

Dr. Båth : The circumstance that the same velocity is found independently of period contradicts the explanation in terms of dispersion curves of Love or Rayleigh waves.

19.— Prof. Gutenberg presents his paper on Crustal Structure in California.

Results on crustal structure in Southern California based on different methods agree. While under the Sierra Nevada a root is found, immediately to the south under the Tehachapi Mountains and to the west under the Coast Ranges no root corresponding to the height of these mountains is indicated. Apparent discrepancies found elsewhere between results from gravity data and from seismic data may result from the assumption in calculations based on gravity observations that the density in the surface layers is the same everywhere. While this assumption has advantages for geodetic calculations on a well defined geoid, it may lead to incorrect conclusions in tectonophysics.

The complete text of this paper is included in B. Gutenberg: Zur Frage der Gebirgswurzeln, *Geologische Rundschau,* Vol. 46, Heft 1, pp. 30-38, 1957.

Prof. Danes refers to the large variation of density in so-called granites.

Prof. Gutenberg says that the best available data still seem to be those of Washington.

Prof. Danes states that his office (Gulf Research and Development Co.) possesses very extensive modern density data and he hopes that it would be possible to arrange for publication.

Prof. Keilis-Borok asks for Prof. Gutenberg's opinion on the number of crustal layers.

Prof. Gutenberg : To a first approximation (which I am ready to alter when new data become available) I would recognize 4 layers : sedimentary, so-called granitic, so-called basaltic, and ultrabasic. The Conrad discontinuity is very definitely recognized in many places, e. g. in the Russian work presented this morning.

20. — *Sir Harold Jeffreys* presents his paper on Elastic Waves in a Continuously Stratified Medium.

Approximate methods have been applied to several problems of internal reflexion in a medium of which the properties are functions of one co-ordinate and vary slowly with position. All the waves are supposed short. It is found that internal reflexion changes the phase by $\frac{1}{2}\pi$ in harmonic waves and so blurs the commencement of a sudden movement.

In the absence of a free surface the movements P and SV are almost independent ; however there is total reflexion in the interior. SH and SV can be propagated in an internal layer of low velocity but produces only slight movement at a free surface if the variation of properties is not small. P-waves in such a layer must suffer attenuation because they are transferred into SV at the free surface.

The complete paper has been published in *Mon. Not. R. Astron. Soc., Geophys. Suppl.,* London, Vol. 7, No. 6, November, 1957, pp. 332-337.

Prof. Pekeris asks if there is a change in the amplitude of SV as you pass the critical distance where P is parallel to the surface. He says that with a simple pulse there is a marked increase in SV beyond the critical distance and he refers to the effect of reflections from the Mohorovičić discontinuity.

Sir Harold Jeffreys says he has not done the arithmetic but he supposes that there would be an increase in the amplitude of SV as Prof. Pekeris has suggested.

Dr. O'Brien also takes part in the discussion, asking about the meaning of small variations of the elastic properties.

The session is closed.

FIFTH SESSION

FRIDAY, SEPTEMBER 6 (afternoon)

Program

9. — Scientific communications : Travel Times, Velocities, and Internal Structure.

21. — *I. Lehmann:* Velocities of Longitudinal Waves in the Upper Part of the Earth's Mantle.

22. — *N. V. Kondorskaya:* Travel Times and Some Dynamic Characteristics of Seismic Waves.

23. — *F. Press* and *M. Ewing:* Current Status of Channel Waves and Their Mechanisms of Propagation.

24. — *L. N. Rykunov:* The Study of a Decrease of P-Wave Amplitudes in the Shadow Zone on a Model.

25. — *R. Teisseyre:* Waves Generated in Seismic Wave-Guides.

26. — *M. Båth :* Some Physico-Chemical Consequences of the Assumption of an Asthenosphere Low-Velocity Layer.

27. — *H. Miki, T. Nishitake, M. Shima, H. Aoki, M. Kumazawa, Y. Shimazu,* and *T. Wada :* Physical State and Chemical Structure of the C-Layer.

28. — *V. A. Magnitsky* and *V. A. Kalinin :* Properties of the Earth's Mantle and Physical Nature of the Intermediate Layer (Layer C).

29. — *A. V. Vvedenskaya* and *L. M. Balakina :* Some Peculiarities of a Displacement Field of P and S Waves Propagating in the Earth's Mantle.

30. — *C. L. Pekeris* and *H. Jarosch :* The Free Oscillations of the Earth.

31. — *B. Gutenberg:* The « Boundary » of the Earth's Inner Core.

32. — *C. L. Pekeris* and *H. Lifson:* The Motion of the Surface of a Uniform Elastic Half-Space Produced by a Buried Pulse.

This symposium has been organized by *Prof. Birch.* The session is opened at 02.00 p. m. with Prof. Birch in the chair.

9. Scientific communications : Travel Times, Velocities, and Internal Structure

21. — *Miss I. Lehmann* reads her paper on Velocities of Longitudinal Waves in the Upper Part of the Earth's Mantle.

In continuation of earlier work it was attempted to approximate the European time-curve for P up to 22° calculating it from assumed velocity functions. — The time-curve was taken to be practically a straight line of slope 13.6 sec/degree up to 15° and to curve from there onwards. The difference of height at 15° and at 22° was taken to be the same as for the Jeffreys-Bullen P curve for a surface focus. — The Mohorovičić function $v = v_0 \left(\frac{r}{r_0}\right)^{-k}$ was taken because calculations become simpler than when the Wiechert formula $v = a - br^2$ is used. — In the layer immediately below the Mohorovičić discontinuity a small velocity gradient must be adopted, but if amplitudes are not considered the velocity can be taken to increase slightly, to be constant or to decrease slightly. Since the transmission times are almost unaffected by the choice made, constant velocity v = 8.12 km/sec was assumed for convenience. — The lower boundary of the layer of constant velocity was tentatively taken at 220 km depth. Here an abrupt increase of velocity gradient was at first assumed, but a better fit to the P curve was obtained when the velocity itself was taken to increase. An increase to 8.5 km/sec was assumed. With the k of our formula = 2.88 (making v increase to 10 km/sec at 560 km depth) an acceptable solution was obtained. The time-curve has a loop, the branches intersecting at 16°. — Time-curves for various depths of focus could now be calculated. It was desirable to make comparison with observation, but there are not many deep earthquakes in Europe. The Rumanian earthquakes having a depth of about 140 km were chosen. The travel times of 7 well recorded earthquakes were compared and found to agree so closely that the foci are likely to be the same. The epicentre cannot be very accurately determined, but the greater part of the stations are in a westerly or north-westerly azimuth, and when their travel times were taken they were found to have a systematic deviation from the calculated times. A smaller velocity increase in the lower layer was assumed and a better fit obtained. — The pP curve has a loop with its lower end extending to a smaller distance than that at which the « first » pP ray emerges. pP is known sometimes to have been observed at «too short» a distance. The available Rumanian observations, however, are not good enough for much information about the pP curve to be derived from them.

The complete paper will be published in the *Annales de Géophysique,* Paris.

Sir Harold Jeffreys: In Miss Lehmann's original paper there were two sets of observations for great distances on the time-distance graph. The later arrivals were referred to as Pd. Do the Pd-observations lie on the line now drawn by Miss Lehmann ?

Miss Lehmann : The later arrivals are too poor to be considered.

Prof. Gutenberg thinks they are a function of the region and that change of temperature with depth is an important factor.

Prof. Bullen : Miss Lehmann took the trial figure of 220 km for the depth of the change in velocities. How far below this is it possible to go compatably with the data, and in particular, is there a change at 400 km ?

Miss Lehmann : I see no evidence for a change at 400 km but of course there is no definite evidence for the absence of change.

Dr. Keilis-Borok : The ambiguities in Pd may be resolved by consideration of the form of the displacement in addition to the arrival time.

Miss Lehmann agrees but says she had not seen the records.

22.— *Mrs. Dr. Kondorskaya* presents her paper on Travel Times and Some Dynamic Characteristics of Seismic Waves.

Earthquake seismograms from various regions of seismic activity, namely, the Far East (a region south-east of the Hokkaido Is, Kamchatka region), Central Asia, Turkey registered by the USSR seismic stations have been studied..

Investigations were conducted for epicentral distances exceeding 10° at comparatively short intervals.

The main seismic elements of the investigated earthquakes were determined by methods independent of travel time curves.

A difference between travel times of *P* and *S* waves as observed (*O*) and as determined (*C*) by the Jeffreys-Bullen travel time curves has been examined for corresponding depths of foci. The nature of such deviations has been brought out. Their regional peculiarities depending on the location of stations have been found.

The travel times to the stations in the Far East, Central Asia and the Caucasus observed for the earthquakes in all above-mentioned regions proved to be larger than those determined by Jeffreys-Bullen travel time curves. The deviations from Jeffreys-Bullen time curves were 2-3 sec for P waves and 6-8 sec for S waves on the average.

The allowance for the above-mentioned station peculiarities makes more accurate epicentre determinations possible.

The deviations may be partially explained by the difference between the structure of the Earth's crust in the investigated regions and the average structure of the Earth's crust all over the globe ; besides, the difference between wave velocities may exert influence on the basalt-ultrabasalt boundary as well as on the layers of the Earth's mantle.

The dependence of different body wave amplitudes and their relations with the epicentral distance have been determined for the earthquakes in the Far East region from observations at the USSR seismic stations, due allowance being made for the existence of preferred directions in the focus emission. The correlation of theoretical and experimental data makes the determination of the location and nature of some boundaries inside the Earth's mantle more precise.

The complete text of this paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

See also a paper by N. V. Kondorskaya in *Izv. Akad. Nauk SSSR, Ser. Geofiz.*, No. 7, pp. 895-913, 20 Figs, 1957.

Dr. De Bremaecker asks if decreasing amplitude could be due to absorption or to other factors such as the geometry of the rays.

Dr. Kondorskaya : It could be due to damping.

Prof. Richter says that the calculation by Dr. Kondorskaya has taken the geometry into account and that the graph represents residuals.

Prof. Bullen asks what the extent of possible allowable deviation from the J.-B. times is.

Sir Harold Jeffreys says he found deviations of 2-3 sec from Japan.

Dr. Båth : What would the effect of slight variations in focal depth be ?

Dr. Kondorskaya : The effect of focal depth has been taken into account. Earthquakes with foci at 30 km have been used for comparison with the J.-B. travel times.

23. — *Prof. Ewing* presents the paper by *F. Press* and *M. Ewing* on Current Status of Channel Waves and Their Mechanisms of Propagation.

In recent years seismologists have recognized channel waves as tools for exploration of the « fine structure » of the earth's crust and mantle. The character of channel waves Lg, Rg, Mg, Pa, Sa, and G have been described but their mechanism of propagation remains to be established. This paper reviews the features of channel waves and offers tentative explanations for their mechanism of propagation involving velocity gradients and spherical curvature of the earth's surface and the M-discontinuity.

A very comprehensive and very excellent treatment of the authors' investigations in this and related fields will be found in the book by W. M. Ewing, W. S. Jardetzky, and F. Press : Elastic Waves in Layered Media, *McGraw-Hill Book Co.,* 380 pp., 154 Figs, 1957.

Dr. Stoneley : I want to congratulate the authors for the extreme beauty of their work. Long ago I tried to integrate group velocity to get phase velocity, but I was unable to determine a constant of integration. Ewing is now virtually supplying this constant, because by differentiation we could get the group velocity.

The authors were indeed much excited by this possibility.

24. — The paper by *L. N. Rykunov,* The Study of a Decrease of P Wave Amplitudes in the Shadow Zone on a Model, is read only in title in the author's absence.

To study the variation of wave amplitude with epicentral distance it is necessary to solve the problem on seismic wave diffraction on the Earth's core. From a large number of works on diffraction related most closely to this problem, quantitative results are obtained only by J. G. J. Scholte [1] who estimates the rate of decrease of P-wave amplitudes with the period of 10 sec for a fixed process and an ideally liquid core.

The comparison of the Scholte results with the seismic data shows that the observed P-wave amplitudes decrease more rapidly than the computed ones. To prove that this difference is the result of the deviation of the true core from the ideally liquid one, one has to find out how the mechanical properties of the matter in the core influence the P-wave diffraction. This problem was investigated by the method of seismic modelling with an ultrasonic seismoscope (as the problem cannot be solved by theoretical methods). In the Earth's model with a mantle made of a paraffino-polyethylenic mixture and meeting all the requirements of similarity, different values were taken for density, all-round bulk modulus and rigidity of the core. The rate of decrease of P-wave amplitudes in the shadow zone was found to be essentially dependent on a change in the rigidity modulus of the core, while the other parameters acquired values near to the similarity demands. A quantitative evaluation of this dependence has shown that it can be used for determining the value of the core rigidity. The solution of the qualitative

(1) U.G.G.I., Comptes Rendus, No. 11, p. 57, 1954.

side of the problem is that the rigidity modulus of the Earth's core is different from zero.

The complete text of this paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

25. — The paper by *R. Teisseyre,* Waves Generated in Seismic Wave-Guides, is read only in title in the author's absence.

A paper entitled Ideal Seismic Wave Guides by R. Teisseyre has appeared in *Acta Geophysica Polonica,* Vol. 5, No. 2, pp. 95-102, 7 Figs, Warsaw, 1957, from which the following summary has been made up.

Some types of surface waves (Lg, Rg) suggest the existence of seismic wave guides. A hypothetical mechanism for channel-wave propagation, suggested by Båth in 1954, has been studied mathematically applying methods used for electromagnetic wave guides. Two types of seismic wave guides are considered : one a low-velocity layer, the other limited by the earth's surface and with downward increasing velocity. Amplitude variations with depth and dispersion curves are derived for P, SV, and SH.

26. — *Dr. Båth* presents his paper on Some Physico-Chemical Consequences of the Assumption of an Asthenosphere Low-Velocity Layer.

Starting from the assumption of a velocity and temperature distribution in the asthenosphere, as given by Gutenberg, values are derived for the pressure and temperature dependence of the bulk modulus and the modulus of rigidity for three depth intervals, i. e. 30-80, 90-140 and 150-200 km. The values obtained are in fair agreement with existing laboratory data. If further laboratory investigations will show that some of the values derived are especially unreasonable, this will call for revisions of the basic assumptions concerning the velocity and temperature distributions.

This paper is a part of a larger paper by M. Båth : Some Consequences of the Existence of Low-Velocity Layers, *Annali di Geofisica,* Vol. 9, No. 4, pp. 411-450, 8 Figs, Rome, 1956.

Prof. Birch : The large variations in the computed pressure and temperature coefficients indicate that the basic assumptions are not mutually consistent.

Prof. Gutenberg : The least probable assumption is that of temperature. A slight change in the temperature curve may be of large influence on the computed quantities.

27.— *Dr. Shimazu* reads the paper by *H. Miki et al* on Physical State and Chemical Structure of the C-Layer.

A polymorphic phase transition hypothesis on the origin of the C-layer, which states a change of crystal structure, is studied based upon solid state physics. The change of $\emptyset = V_p^2 - \frac{4}{3} V_s^2 = K/\rho$ by polymorphism is calculated for some simple hypothetical transitions. An approximate expression of the equation of state of the form $-\frac{A}{r} + \frac{B}{r^n}$ is assumed. The increase of $\emptyset$ accompanying the density increase is deduced only for $n > 7$. A little more accurate expression of the equation of state which includes the term of the thermal vibration of lattice is also used. Assuming the B and D layers to be of NaCl and CsCl types respectively the change of Ø is inferred. The calculated change of Ø is far less than the observed value. Olivine to spinel transition of Mg_2SiO_4 is also discussed based upon an equation of state of the form $-\frac{A}{r} + Be^{-\gamma r}$. Though our expression of the equation of state is very approximate, it is concluded that the change of Ø in all the above transitions cannot explain the observed increase of Ø in the C-layer.

A chemical phase transition hypothesis, which states a chemical inhomogeneity, is studied based upon an idea that a gravitational separation due to density differences as well as a chemical interaction among components controls the equilibrium arrangement of stable phases. A balance of possible reactions among $MgSiO_3$ -- Mg_2SiO_4 — MgO — SiO_2 with upward squeezing of coesite phase of SiO_2 is calculated. It is concluded that $MgSiO_3$ decomposes into Mg_2SiO_4 at 200 km depth and Mg_2SiO_4 into MgO at 600 km depth. If the compressible property of the system is taken into consideration the decomposition is realized at a little higher level. It is remarkable that the Ø of MgO is nearly equal to the observed Ø in the D-layer. Fe_2SiO_4 decomposes into FeO at 100 km depth. However, FeO—MgO mixture is more unsuitable since the Ø of FeO is smaller than that of MgO. Assuming the oxide model we can calculate the abundance ratio of elements for the whole earth. The oxide model is not unreasonable as well as the other familiar models.

On an assumption of an ideal solution for the materials composing the earth, a simplified chemical model of the earth is discussed. In a Fe — Si — O system model, it is shown that Fe_2SiO_4 and Fe make the mantle and core respectively. Fe_2SiO_4 is split into oxide at the lower mantle.

One important feature of the C-layer is its transient character with several hundred kilometers width. At several hundred kilometers depth the olivine may be nearly unstable and a small perturbation energy is necessary to start the endothermic reaction of decomposition. Applying a theory of thermodynamics with irreversible processes for a coupling of reaction, heat and material flows, it is shown that a local heat concentration excites and maintains the steady state coupling when the squeezing velocity is much slower than the reaction rate. The local fluctuation of temperature will be realized by a radioactive matter concentration or by a thermal convection within the D-layer. An increase of diffusivity by rising temperature and a decrease of melting point during the upward migration facilitate the squeezing. The crust of the earth, which is inferred as the product of the squeezed SiO_2, has only 7 % of the total squeezed mass. If the squeezing is completed the earth loses its mass corresponding to 300 km in radius at the surface. However, the depth of decomposition shown before is only the minimum value. If the diffusivity of squeezing is so small that the squeezing is not yet completed the olivine remains as a metastable state even at the layer deeper than 600 km. This circumstance has a relation to the fact that the maximum depth of deep-focus earthquakes is found there.

From a thermodynamical view point the two hypotheses, viz. polymorphic and chemical transitions, have similar characters of endothermic reaction with volume decrease. The significant difference is, however, that the polymorphism is a reversible reaction while the reaction with squeezing is irreversible. The slowly changing character of the C-layer can also be explained by the differences of the decomposition depth of various components. However, a balance between squeezing velocity and chemical reaction rate can explain it much more reasonably. A jump in the activation energy of the electric conduction is studied for both hypotheses based upon a theory of solid state physics.

This paper is a summary of the following papers.

MIKI (H.), Is the layer C (410-1,000) inhomogeneous ?, *Jour. Phys. Earth, 3,* 1-6, 6 figs.; Seism. Soc. Japan, 1955.

MIKI (H.), On the C layer, *Jour. Seism. Soc. Japan, 8,* 162-164, 4 figs.; Seism. Soc. Japan, 1956. — On the C layer (continued), *Jour. Seism. Soc. Japan, 9,* 58-59, 1 fig.; Seism. Soc. Japan, 1956.

SHIMA (M.), On the variation in bulk modulus/density in the mantle, *Jour. Phys. Earth, 4,* 7-10, 2 figs.; Seism. Soc. Japan, 1956.

SHIMAZU (Y.), T. Wada & H. Aoki, Polymorphism of forsterite and the origin of the C layer within the mantle of the earth, *Jour. Earth Sci.*, 11 pp., 3 figs.; Nagoya University, Japan (in preparation).

SHIMAZU (Y.), Equation of state of materials composing the earth's interior, *Jour. Earth Sci., 2,* 15-172, 26 figs.; Nagoya Univ., Japan, 1954.

SHIMAZU (Y.), Chemical structure and physical property of the earth's mantle inferred from chemical equilibrium condition, *Jour. Earth Sci., 3,* 85-90; Nagoya Univ., Japan, 1955.

SHIMAZU (Y.), Chemical phase equilibrium and physical structure within the earth's mantle, *Jour. Phys. Earth, 4,* 1-6, 3 figs.; Seism. Soc. Japan, 1956.

SHIMAZU (Y.), Chemical equilibrium within self-gravitating planets and internal constitution of the earth, *Jour. Phys. Earth, 4,* 43-47, 3 figs.; Seism. Soc. Japan, 1956.

SHIMAZU (Y.) & M. KUMAZAWA, Equilibrium conditions of $2MgO + SiO_2 \rightleftarrows Mg_2SiO_4$, *Jour. Seism. Soc. Japan, 9,* 57; Seism. Soc. Japan, 1956.

SHIMAZU (Y.), A chemical phase transition hypothesis on the origin of the C layer within the mantle of the earth, *Jour. Earth Sci.*, 4 figs.; Nagoya Univ., Japan (in preparation).

SHIMAZU (Y.), A theory of physico-chemical reactions under a non-uniform field and its application to a thermodynamical study of the earth, *Jour. Earth Sci.,* Nagoya Univ., Japan (in preparation).

This paper is discussed together with the following paper, which is closely related to it.

28. — *Prof. Magnitsky* presents the paper by himself and *V. A. Kalinin* on Properties of the Earth's Mantle and Physical Nature of the Intermediate Layer (Layer C).

1. According to the data on velocities of seismic waves the Earth's mantle can be divided into three layers: the upper (layer B), intermediate (layer C) and lower (layer D).

2. The mode of change in the ratio of the bulk modulus to the density $\frac{k}{\rho}$ in the layer D as well as the magnitude of the derivative $\frac{dk}{dp}$ indicate that the layer D can be considered homogeneous in its composition at first approximation ; the same can be said about the layer B, though with less accuracy.

3. Two main hypotheses were put forward about the nature of the layer C :

1) at a depth of 400—900 km a change of the chemical composition takes place in the layer C;

2) the modification of the lattice in the layer C takes place without an essential change of the chemical composition.

4. Experiments made by P. W. Bridgman regarding polymorphic transitions at high pressures as well as theoretical considerations permit us to insist that a simple rebuilding of the lattice can hardly produce the required change of density and other mechanical properties of the layer C.

Besides that a simple change of the lattice type cannot account for a rapid increase of electric conductivity at corresponding depths. A rapid change of the chemical composition also seems rather improbable.

5. To explain uncommon properties of the layer C, the authors put forward the hypothesis that in this layer the transition from the ionic type of bonds prevailing in the layer B to the covalent one takes place. Such a transition is caused by an increased overlapping of the electronic clouds of neighbouring atoms during the shortening of interatomic distances effected by high pressure which brings into being intensive attractive exchange forces. In its turn this urges the density to increase and elastic modulus to grow.

6. A mere substitution of interionic distances for those obtained by covalent radii, makes for a density increase by 18 per cent which rather well agrees with the Bullen data. The change of $\frac{k}{\rho}$ also well agrees with the observed values 1.9 (km per sec)^2 and 1.5 (km per sec)^2 from seismic evidence.

7. Calculations have been made to get the coefficients of the equations of state for the ionic and covalent types of bonds according to B. I. Davydov with the use of experimental values of $\frac{k}{\rho}$ in the layers B and D.

The correlation of the obtained curves for the energy has shown that the hypothesis on the ionic type of bonds in the layer D contains a principal contradiction and so seems to be rejected. The hypothesis on the valence type of bonds is concordant with experimental data, but requires a small increase of the density in the layer D as compared with the density in the model A of K. E. Bullen.

8. A rapid increase of electric conductivity in the layer C seems to be explained by the transition from the ionic conductivity type to the semi-conductor type.

9. The correlation of experimental data obtained by P. W. Bridgman for olivine with seismic data has shown that the upper part of the mantle may be built neither of olivine tested by P. W. Bridgman, nor of relative rocks (dunite, peridotite). Initial parts of such curves coincide but the inclinations of theoretical and experimental curves sharply diverge.

The complete text of this paper will be published in *Publications du Bureau Séismologique International, Série A, Travaux Scientifiques, Fasc. No 20.*

Prof. Danes asks if Dr. Miki et al have taken capillary forces into account.

Dr. Shimazu : Yes.

Dr. Ringwood quotes figures on the transition pressures of forsterite, fayalite, and other substances. He says than van der Waal's forces had not been taken into account by Miki et al, and that he thinks spinels have the right sort of properties.

Prof. Birch agrees with Dr. Ringwood's comment on spinels.

Dr. Shimazu : The study was not based on the correct equation of state, but I think a density increase of about 10 % may be reasonable.

Prof Birch : There is no direct evidence, but Al-spinel gives k/ρ about 50 $(km/sec)^2$.

Dr. Shimazu says that if ρ increases by 10 %, then k must increase very much, to which *Prof. Birch* agrees.

Dr. Scheidegger asks Prof. Magnitsky about the possibility of convection currents cutting across the layers.

Prof. Magnitsky says may be they can, but he does not see how.

Prof. Birch says that if you build upon the seismic conclusions, you have already assumed homogeneity.

29. — The paper by *A. V. Vvedenskaya* and *L. M. Balakina,* Some Peculiarities of a Displacement Field of P and S Waves Propagating in the Earth's Mantle, is read only in title in the authors' absence.

The study of the Earth's mantle structure by seismic methods is mainly based on data on the propagation velocities of *P* and *S* waves at various depths. The values of seismic wave velocities are usually determined from travel time curves.

In this paper an attempt is being made to utilize observations of P and S displacement amplitudes for studying peculiarities of the structure of the Earth's mantle.

The use of the dislocation theory formulae for determining displacement fields of earthquakes is based on the assumption of a fault in the continuous medium of the focus. In this paper the Nabarro solution is applied as suggested to describe the displacement fields of the Burgers dislocation.

The results obtained indicate that at epicentral distances of 18—20, 35—45, 52—55, 68—71° and about 80° corresponding to depths of the ray penetration to 250—500, 900—1000, 1200—1300, 1900—1950 and 2300 km a noticeable increase of P displacement amplitudes as against SH waves is observed. At the same epicentral distances a displacement increase of SV waves is found with respect to SH waves. These relations are identical in their character.

The depths mentioned above are meant for the discontinuities in the Earth's mantle discovered earlier. The use of the dislocation theory formulae made it possible to reveal some peculiarities of the S and P wave propagation in the Earth's mantle.

The complete text of this paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

30.— Prof. Pekeris presents the paper by *C. L. Pekeris* and *H. Jarosch* on The Free Oscillations of the Earth.

A systematic study was made of the free oscillations of the earth. Three methods of approach were followed. In the first, the periods of free oscillation of a *uniform* earth possessing the average properties of the real earth (the « average model ») were investigated analytically. In the second, the periods of free oscillation of the *real* earth, as represented by Bullen's model *B*, were determined by the use of a variational method. In the third method an exact solution for the real earth was obtained by integrating the differential equations numerically on the electronic computer (WEIZAC).

It was found that the results obtained by the variational method agreed well with those derived from the exact solution, as is shown in Table 1.

Model Earth	n = 0	2	3	4	Method
« Average model »	26 m 40 s	44 m 17 s			Variational
	26 m 42 s	44 m 17 s			Exact
Bullen's model *B*	20 m 40 s	52 m 57 s			Variational
	20 m 44 s	54 m 56 s	39 m 56 s	35 m 43 s	Exact

Table 1. The fundamental periods of free oscillation of spherical harmonic type of order n.

The highest period of free oscillation is 55 minutes for the spheroidal type. This value is close to the value of 57 minutes which Benioff observed in the Kamchatka earthquake of 1952, and which he attributed to a spheroidal free oscillation.

The paper has been published in the *Contributions in Geophysics,* Vol. 1, pp. 171-192, Pergamon Press, 1958.

Prof. Benioff mentions the possibility of torsional oscillations in connection with transcurrent faulting.

Prof. Pekeris thinks such oscillations will have shorter period.

Dr. Stoneley asks about sensitivity to densities of surface rocks and whether there would not be a slight preference for one kind of oscillation due to difference between continents and oceans.

Prof. Pekeris says that more details are needed.

Prof. Satô says he has computed a period less than 50 minutes.

Mrs. Jobert : J'ai fait un calcul approché sur un problème analogue pour les oscillations libres d'un modèle avec un noyau liquide homogène et un manteau solide homogène, la période est un peu supérieure à 56 min—valeur voisine de celle donnée par le Prof. Pekeris. Celle-ci semble un peu plus faible que la période de 57 minutes observée par le Prof. Benioff. Cette différence a-t-elle une signification physique ?

Prof. Benioff : The computed periods are within the limits of error of the observed period. The earth has not responded since more complete apparatuses were set up, but the period is roughly 52-57 minutes.

Dr. Stoneley asks if the coming nuclear detonation could have an effect.

Prof. Benioff and *Prof. Birch* do not think so.

31.— Prof. Gutenberg presents his paper on The « Boundary » of the Earth's Inner Core.

Longitudinal waves PKIKP with periods of about one second which have passed through the inner core frequently arrive earlier than the corresponding waves with periods of several seconds. At epicentral distances between about 120° and 135° the difference in arrival between the first short-period waves and the long-period main impulse may reach nearly 20 seconds. If this difference is a consequence of dispersion in a transition zone between the outer and inner core, the calculated « radius » of the inner core is greater for short-period than for long-period waves. According to theoretical and laboratory research by Kuhn and Vielhauer such phenomena are to be expected if the transition from the outer to the inner core corresponds to a relatively rapid but gradual increase in viscosity without change in material. On the other hand, findings from all sources agree with the hypothesis that the boundary between mantle and core separates solid material (rock) in the mantle from a different liquid material (mainly iron) in the core.

The complete paper has been published in *Trans. Amer. Geophys. Union,* Vol. 38, pp. 750-753, 3 Figs, 1957.

Dr. Båth : In addition to the doubling of PKP we have observed repeatedly a similar doubling of P'P', although the phases are usually less defined in the latter case.

32. — *Prof. Pekeris* presents the paper by himself and *Mrs. H. Lifson* on The Motion of the Surface of a Uniform Elastic Half-Space Produced by a Buried Pulse.

An exact solution is obtained for the motion of the surface of a uniform elastic half-space due to the application at a depth H below the surface of a concentrated vertical force. The time-variation of the applied force is assumed to be represented by the Heaviside unit function. The solution for the horizontal and vertical components of displacement is cast in the form of single integrals over a fixed range, and these have been evaluated on the electronic computer of the Weizmann Institute (WEIZAC). The assumed source emits both S-waves and P-waves. Beyond a distance r_1 from the epicenter, which is equal to $H/\sqrt{2}$ in the case $\lambda=\mu$, the original S-wave is converted on reaching the surface into a diffracted SP-wave travelling along the surface. At large ranges, the SP-phase is more pronounced than the P-phase. The S-phase is marked by a finite jump for $r < r_1$, and by a logarithmic infinity for $r > r_1$. The coefficient of the logarithmic term is zero both at $r = r_1$ and for large ranges, having a maximum value at an intermediate range. There is no Rayleigh wave at $r < r_1$. At large ranges $(r/H > 1)$ the solution, as a function of the reduced time $T = ct/R$, approaches the form of the solution for the surface pulse.

The complete paper has been published in *The Journal of the Acoustical Society of America,* Vol. 29, No. 11, November, 1957, pp. 1233-1238, 7 Figs.

Dr. Oliver asks if the higher modes could be accounted for by ray theory.

Prof. Pekeris says that everything can be explained by ray theory.

Mrs. Labrouste invites the delegates to order her travel time graphs, after which the session is closed at 05.50 p.m.

SIXTH SESSION

SATURDAY, SEPTEMBER 7 (morning)

Program

9. — Scientific communications : Crustal Structure of Continents and Ocean Basins (cont.).

33. — *P. Caloi :* Caratteristiche della crosta terrestre, quali risultano dallo studio dei terremoti e delle grandi esplosioni.

34. — *P. Caloi :* «Radici» delle montagne, con particolare riguardo alle Alpi Meridionali e agli Appennini Centro Settentrionali.

35. — *P. Caloi :* Differenze strutturali fra Sistema Alpino e Valle Padana.

36. — *F. Press :* New Seismic Methods for Investigation of Crustal Structure.

37. — *P. G. Gane :* Seismic Work on Crustal Structure in South Africa.

38. — *F. Neumann :* Crustal Structure in the Puget Sound Area.

39.— *J. Oliver* and *M. Ewing :* Propagation of Continental Love and Rayleigh Waves in the Fundamental and Higher Modes.

40.— *Y. Labrouste* and *J. P. Rothé :* Expériences séismiques dans les Alpes occidentales en 1956 ; Résultats obtenus par le « Groupe d'Etudes des Explosions Alpines ».

This is a continuation of the symposium, organized by *Prof. Press* (Fourth Session, September 6, morning). The session is opened at 09.00 a.m. with Prof. Press in the chair.

9. Scientific communications : Crustal Structure of Continents and Ocean Basins (cont.)

33.— *Prof. Caloi* reads his paper on Caratteristiche della crosta terrestre, quali risultano dallo studio dei terremoti e delle grandi esplosioni. The presentation is made in French.

Non sempre i risultati dell'interpretazione delle registrazioni provocate da terremoto hanno coinciso — per una data regione — con quelli dedotti da grosse esplosioni. Anzi, spesso furono contrastanti. Bouasse attribuiva senz'altro il contrasto al fatto che le registrazioni relative ad esplosioni erano difettose, per deficienza di energia in giuoco. E — almeno per la sua epoca — non aveva torto. Negli ultimi anni l'energia sviluppata dalle esplosioni è stata enormemente aumentata, così da consentire attendibilità all'inizio delle registrazioni.

Esistono però altrè difficoltà, che si riferiscono sopratutto all'interpretazione delle fasi successive.

Ad ogni modo, specie sulla base dei risultati ottenuti recentemente in America nella registrazione di grosse esplosioni, sembrava che i dati forniti dalla Sismologia dovessero essere più o meno modificati. Quì si prova che ciò non risponde a verità, almeno per quanto si riferisce al continente euro-asiatico, dove non esistono sostanziali contrasti fra dati forniti dalle ricerche sismologiche e quelli ottenuti dalle grandi esplosioni. Per quanto concerne il valore medio della stratificazione del così detto « granito », lo spessore di 18-20 km ottenuto da Caloi nel 1943 è stato confermato sia da successive ricerche sismologiche, sia dallo studio delle grandi esplosioni (studio condotto da francesi, tedeschi, ungheresi e russi principalmente), come valore predominante in gran parte del continente euro-asiatico, fatto esclusione dei bordi continentali — dove risulta decisamente meno potente — e dei sistemi di montagne, dove forse assume valori più piccoli (almeno come risulta nelle Alpi meridionali). Anche la velocità media di 5,7 km/sec, ottenuta con gli studi sismici è confermata dalle grandi esplosioni, le quali — in conformità con i dati sismici — forniscono pure valori alquanto minori (5,1 km/sec).

Vengono riassunti i risultati ottenuti nelle due vie, con particolare riguardo all'Europa centro-meridionale.

The complete text has appeared in *Annali di Geofisica,* Rome, Vol. X, No. 3-4, pp. 183-188, 3 Figs, 1957.

The discussion is postponed until after the following two papers, which deal with closely related subjects.

34. — *Prof. Caloi* reads his second paper on «Radici» delle montagne, con particolare riguardo alle Alpi Meridionali e agli Appennini Centro Settentrionali.

Il problema delle «radici» delle montagne è ancora controverso. La loro esistenza è stata affermata da Gutenberg per la catena del Nevada e da Caloi per le Alpi e gli Appennini. Altri hanno negato la loro realtà. Sembra però ormai fuori di dubbio che in corrispondenza dei sistemi di montagne la crosta terrestre presenti i massimi spessori.

Anche le esperienze condotte su grandi esplosioni — specie quelle compiute dai russi — conducono alla stessa conclusione.

Restava piuttosto da stabilire quale delle tre stratificazioni formanti la crosta terrestre costituisce la così detta «radice». In un primo tempo, per quanto concerne le Alpi, sembrava che il «granito» costituisse la vera e propria radice. Recenti esperienze, condotte nelle Alpi meridionali (a Nord del Cansiglio) provano però che, quello precedentemente considerato come strato unico, consiste realmente di due strati sovrapposti: il «granito» e lo strato intermedio. Lo strato esterno del granito ha uno spessore di 13 km ca., inferiore quindi alla media continentale di questo strato: pertanto, nelle Alpi meridionali almeno, la «radice» risulta costituita dallo strato intermedio.

Per l'Appennino è probabile una soluzione analoga: ad ogni modo, anche in corrispondenza dell'Appennino centrale la crosta terrestre si presenta con uno spessore complessivo nettamente superiore a quello ammesso per le zone continentali.

Nel lavoro sono pure riportate le caratteristiche sismiche fondamentali della Valle padana.

The complete text has appeared in *Annali di Geofisica,* Rome, Vol. X, No. 3-4, pp. 189-192, 3 Figs, 1957.

35. — *Prof. Caloi* reads his third paper with the title Differenze strutturali fra Sistema Alpino e Valle Padana.

Viene fatto un esame particolare della situazione geologica fra Alpi centro-orientali e Valle del Pò, quale risulta dalle ultime ricerche sismologiche.

Precedenti indagini condotte, durante parecchi anni, nell'ambito del sistema alpino centro-meridionale-orientale, mediante l'ausilio di un vibrografo «Askania» a tre componenti, mi avevano portato a conclusioni in apparenza insostenibili. Sulla base di profonde e strette valli prealpine ed alpine e sui dossi di alcuni massicci dolomitici, la velocità di propagazione delle onde longitudinali risultava elevatissima, dell'ordine di 7.5 km/sec. Tali velocità erano invariabilmente associate alle massime frequenze: in altri termini, contrariamente ad alcune recenti affermazioni, appariva evidente che — come del resto si verifica in altri campi della Fisica — il *massimo di velocità si associa al massimo di frequenza.* La teoria della firmo-elasticità mi consentiva di provare che, sismologicamente parlando, quelle velocità sono riducibili a 5.8 km/sec, che sono appunto quelle — in media — proprie del «granito».

Ne risulta che (almeno in corrispondenza delle Alpi centro-orientali), la superficie esterna, terminale del «granito» si eleva gradualmente a mano a mano che si procede dal centro della Val Padana alle Dolomiti.

Per effetto di erosione, la copertura quaternaria è quasi del tutto scomparsa nei massicci dolomitici, così che in essi il «granito» è pressochè affiorante.

Se consideriamo pertanto una sezione Val Padana-Alpi, da Bologna, alla Marmolada, il limite esterno del granito passa da 7 km circa sotto il livello del mare (centro della Val Padana) ai 2.5—3 km circa sopra il livello del mare nelle Dolomiti.

In altri termini, nei rispetti delle Alpi, la Valle del Pò assume gli aspetti che certe fosse oceaniche assumono nei riguardi di alcuni arcipelaghi dell'Oceano Pacifico.

The complete text has appeared in *Annali di Geofisica,* Rome, Vol. X, No. 3-4, pp. 209-210, 1 Fig., 1957.

Mr. Goguel : A-t-on essayé de combiner les résultats de la séismicité avec ceux de la gravimétrie ?

Prof. Caloi : Non.

Prof. Morelli : Un travail est en préparation à ce sujet.

Mr. Goguel : Dans les gorges étroites il y a contrainte, les roches sont en compression de sorte que les vitesses de propagation peuvent être très élevées. Par contre quand les vallées sont larges, les roches sont détendues et fissurées.

Prof. Caloi : La compression d'une part et la fissuration d'autre part joue un rôle sur les valeurs des vitesses, mais ces deux phénomènes ne peuvent expliquer complètement les variations des vitesses observées.

Prof. Glangeaud : M. Caloi a-t-il tenu compte de la déformation plio-quaternaire ? Toute la Méditerranée s'est enfoncée à cette époque. C'est un problème de compensation de volume.

36. — *Prof. Press* presents his paper on New Seismic Methods for Investigation of Crustal Structure.

The use of phase velocity of surface waves to investigate crustal structure is critically evaluated. Under suitable conditions this method can yield information in regions where seismic refraction methods are difficult to apply, such as mountain chains and continental margins. Examples are given of successful application of the method in Southern California and in the San Francisco Bay region.

The complete paper will be published in the *Bulletin of the Geological Society of America.* See also the following publications by the same author, dealing with the same subject :

Determination of Crustal Structure from Phase Velocity of Rayleigh Waves, Part I : Southern California, *Bull. Geol. Soc. Amer.,* Vol. 67, pp. 1647-1658, 9 Figs, December, 1956.

Determination of Crustal Structure from Phase Velocity of Rayleigh Waves, Part II : San Francisco Bay Region, *Bull. Seism. Soc. Amer.,* Vol. 47, No. 2, pp. 87-88, 1 Fig., April, 1957.

A Seismic Model Study of the Phase Velocity Method of Exploration, *Geophysics,* Vol. 22, No. 2, pp. 275-285, 10 Figs, April, 1957.

Father Ingram : What is the largest size of triangle and the optimum size used in your grid ?

Prof. Press : About 600 km was largest side and the optimum depends on region being investigated in that regional homogeneity leads to easier interpretation.

Dr. Carder : What are the assumptions of speeds and layering in the crust ?

Prof. Press : All methods of exploration make some assumptions. The phase-velocity method assumes :

1) Thicknesses of layers (if present) increase in the same proportion.

2) Phase-velocity variations are due to thickness changes and not to velocity changes.

3) The average thickness of the African crust is 35 km.

Independent of these assumptions are the experimental data which establish a correlation between phase velocity and Bouguer gravity anomaly. The phase velocity decreases as the Bouguer gravity anomaly becomes more negative.

Prof. Pekeris : I notice that the observed points fit the African curves at around 25 sec, but that at around 18 sec the observed points fall distinctly *below* the African curves. Would not that indicate that the top portion of the crust in California is of lower speed than in Africa ?

Prof. Press : The « tailing » effect which you refer to occurs for periods less than 17 sec. Since the velocities are below those possible for the known velocity-depth distribution, these data are not considered in the depth calculation. The cause of this phenomenon is the subject of further study.

Dr. Walter : Have you found agreement with other measurements of thickness based on studies of local earthquakes. For example, work at St. Louis by A. Walter in 1940 showed a structure 37 km thick which compares well with the results shown of 35 km. Has this type of agreement been widespread for other areas ?

Prof. Press : The results seem to agree with refraction measurements near St. Louis as well as in California.

Dr. Walter : Are you concerned about differences of 5 km ?
Prof. Press : Yes.

See also remark by *Prof. Woollard* under No. 38 below.

37. — The paper by *Dr. Gane,* Seismic Work on Crustal Structure in South Africa, is read only in title in the author's absence.

Seismic observations were continued using the now well-established radio triggering technique between a master station in Johannesburg and a single mobile field station situated from 50 to 500 km away. The vibrations observed originated from the « earth tremors » which are occasioned by mining on the Witwatersrand

and which occur several times a day within a limited epicentral area. A network of eight radio telemetering stations distributed about this area served to locate the epicentres.

Traverses were made to the SSW, E and NNE of Johannesburg and the results compared with previous work carried out to the west. No significant differences in the thickness of the crustal layer appear to exist in these directions, nor is there any appreciable dip of the Mohorovičić surface. Combination of all available results from over 400 seismograms gives :

	Depths and Velocities	
	From P phases	*From S phases*
Superficial layer	1.3 km (5.40 km/sec)	1.3 km (3.20 km/sec)
Continental crust	33.8 km (6.18 km/sec)	32.0 km (3.66 km/sec)
Top of mantle	8.27 km/sec	4.73 km/sec
Depth of crust	35.1 ± 1.2 km	33.3 ± 1.3 km

Owing mainly to an inability to fix epicentres and focal depths of the rockbursts to an adequate degree of accuracy, the residuals of individual readings were found to be of the order of 0.25 sec. Within the degree of accuracy implied by this figure, no curvature of the travel-time graph was evident, and there have been only vague indications of phases corresponding to a layer of intermediate velocity, wherefore it seems that no such layer exists generally, and the crust is on the average uniform for a large proportion of its depth.

On the northern traverse, which lay over the deep basin-like structure of the Bushweld Complex, there was a distinct weakness in the Pn phases, and an almost total loss of the Sn phases, which indicates that in such territory there could well be no Mohorovičić layer at all, in the sense of a plane horizontal interface between crust and mantle. A similar loss of the S - phase has been observed in the crust where the ray path has passed through the deep Vredefort dome structure. It is evident that local inhomogeneities in velocity occur which can upset the validity of representing continental structure by means of homogeneous layers with plane interfaces.

It is interesting to note that although this work was done on a plateau nearly 2 km above sea-level, the crustal depth here found is not substantially greater than has been found elsewhere.

The complete text will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.* See also a paper by P. G. Gane, A. R. Atkins, J. P. F. Sellschop, and P. Seligman, Crustal Structure in the Transvaal, *Bulletin of the Seismological Society of America,* Vol. 46. No. 4, pp. 293-316, 8 Figs, October, 1956.

38. — *Prof. Neumann* presents his paper on Crustal Structure in the Puget Sound Area.

Data from three seismograph stations in British Columbia and in Seattle, Washington, are inconsistent with any type of normal continental structure assumed for this area. This is not surprising in view of the abnormal gravity anomalies present.

In studying local shocks 5.8 km/sec was the lowest P wave velocity found south of the border. Canadian seismologists found approximately 6.4 km/sec from explosion tests made on Vancouver Island. These two figures represent the limits of velocities obtained by Tuve and Tatel (for distances under 250 km) from explosion tests in the Sound area. A 7.0 km/sec velocity was provisionally adopted for the zone above the Mohorovičić discontinuity because it is present in other west coast areas.

Because it was impossible to fit the seismograph data to any simple pattern of parallel layering, the following procedure was used in developing regional travel times. It was assumed that the true travel time of P from focus to station would not differ too much from a travel time based on the assumption that the wave followed a direct linear path between focus and station, and traveled at a speed equal to that found in the layer containing the focus. For foci beneath the top layer the travel times would be theoretically too short, but errors would be no greater than those from other sources and are subject to later modification. A set of theoretical P wave travel time curves covering various focal depths was constructed for each of the three velocities named.

In locating earthquakes average values of origin time obtained from the equation $(P - H) = 1.37\,(S - P)$ were used. Epicenters and depths were obtained by fitting the $(P - H)$ values to the particular travel time curve (in the three sets of curves constructed) that yielded epicentral distances consistent with a common geographical point and focal depth. Each solution thus furnished an epicenter, a focal depth, and the speed in the rock at that depth. Enough data of this kind would provisionally outline, in location and depth, the deep crustal structure of the Puget Sound area. Current results are very promising.

With about 40 earthquakes located to date, it appears that the crustal rocks in the area must reach double the depth of normal continental structure, a conclusion that accounts for consistently late P wave arrivals at Seattle and the frequent placing of this station in the « unreliable » category.

The complete paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Prof. Slichter: Has the area been flown magnetically ? Woollard states that over a limited area in Puget Sound there is a certain degree of correlation between magnetic and gravity anomalies.

Mr. L. W. Maley : An aeromagnetic survey, 12 miles wide and paralleling the 49th parallel, has been flown from the west coast of Vancouver Island to Lethbridge, Alberta. Data will be published shortly.

Dr. Båth : You mentioned « unreliability » — late arrivals in this case. I wonder if they could be explained — not only qualitatively, but also quantitatively — by the velocity distribution shown.

Prof. Neumann suggests that they probably could be.

Prof. Birch : « Unreliability » is a bad term for a local anomaly, which pin-points places of interest.

Prof. Neumann : « Travel time anomaly » might be a good term to use or « station constant ».

Prof. Woollard : The work of Ewing and Press on the use of phase velocity dispersion for determining crustal structure gives results that are in excellent agreement with gravitational studies concerning variations in structure. The anomalous relations between gravitational and seismic measurements based upon explosive blasts as reported by Tuve and Tatel in the Colorado Plateau are not observed with the phase velocity measurements. The anomalous seismic structure found by Neumann in the Puget Sound area of Washington and British Columbia is also in agreement with the gravitational interpretations of the conditions there. It appears therefore that regional gravitational data can be used with a reasonable degree of assurance for deducing crustal structure despite the inherent ambiguity of gravity interpretation. The precautions required are that a reliable seismic section as is known in the ocean areas be used as starting point and the change in regional gravity from such a starting point be related principally to the density contrast associated with the Mohorovičić discontinuity. A density contrast from 2.84 g/cm^3 to 3.27 g/cm^3 appears to give fairly good correlations with the phase velocity measurements. The complexity of regional gravity variations over North America and Europe indicate that there may be quite a few areas of anomalous seismic structure within the crust as observed in Puget Sound.

39. — *Dr. Oliver* presents the paper by himself and *Prof. Ewing* on Propagation of Continental Love and Rayleigh Waves in the Fundamental and Higher Modes.

The velocity structure within and directly beneath the continental crust may be deduced from the dispersion of seismic surface waves of periods varying from 0 to about 75 seconds. Recent identification and study of wave trains with periods less than 20 seconds corresponding to higher modes of both the Love and Rayleigh types provides additional information on this structure. The data include measurements of group velocity along the entire path between epicenter and station and of both phase and group velocity across an array in eastern North America.

The dispersion curves and wave types may be explained qualitatively by a model consisting of a homogeneous crust overlying the mantle. A more quantitative explanation, however, calls for a substantial increase of velocity with depth within the crust.

The complete text of the paper by J. Oliver and M. Ewing is published in two parts :

1) Higher Modes of Continental Rayleigh Waves, *Bulletin of the Seismological Society of America,* Vol. 47, No. 3, pp. 187-204, 9 Figs, July, 1957.

2) Normal Modes of Continental Surface Waves, *Bulletin of the Seismological Society of America,* Vol. 48, No. 1, pp. 33-49, 15 Figs, January, 1958.

40. — *Mme Labrouste* presents the paper by herself and *J. P. Rothé :* Expériences séismiques dans les Alpes occidentales en 1956 ; Résultats obtenus par le « Groupe d'Etudes des Explosions Alpines ».

La Commission Séismologique Européenne, réunie à Rome en 1954, a recommandé que des expériences systématiques soient exécutées dans les Alpes afin de donner une solution à l'un des grands problèmes de la géophysique, à savoir la structure profonde des chaînes de montagnes. Le Comité National Français s'est préoccupé de répondre à ce vœu et a préparé un projet comportant l'exécution de deux séries d'expériences, mettant en œuvre des charges de 5 à 20 tonnes, l'une dans le Briançonnais et l'autre dans le Massif granitique du Pelvoux.

La première partie du projet a pu être réalisée du 24 août au 6 septembre 1956 avec la participation d'équipes allemandes, italiennes et françaises. De nombreux organismes (et en premier lieu les services de la Défense Nationale) ont prêté leur concours à l'exécution des expériences.

Les explosions ont eu lieu au lac des Rochilles, sur l'axe de la zone houillère briançonnaise. Sur le profil longitudinal, les mesures mettent en évidence, à une profondeur d'environ 2 km, un milieu caractérisé par une grande vitesse (v = 6 km/s) dont la limite supérieure doit constituer une surface de discontinuité. Cette surface est définie aussi bien dans la première partie du profil où les stations sont situées dans la zone interne briançonnaise que dans la deuxième partie où le milieu à grande vitesse doit correspondre au socle cristallin, prolongement du Massif du Mercantour. Les résultats séismiques ne confirment donc pas l'hypothèse d'un enfoncement en profondeur des terrains sédimentaires du Briançonnais. Sur le profil Ouest, les ondes se sont propagées à la surface du sol dans les gneiss et granites jusqu'aux environs de Grenoble ; au delà, les temps d'arrivée accusent des retards plus ou moins importants, traduisant une plongée vers l'Ouest de la limite supérieure du socle. Les ondes enregistrées en quelques stations entre 82 et 138 km pourraient être des ondes Pb (v = 6,7 km/s). La discontinuité de Conrad serait un peu plus profonde (25 km environ) en bordure ouest des Alpes françaises que plus au nord, sous le plateau souabe par exemple (18 à 20 km). Des résultats analogues ont été trouvés sur un profil Est avec une vitesse de 6,7 km/s et une profondeur probable de 23 km pour la discontinuité de Conrad ; l'épaisseur du « basalte » semble très faible (5 à 7 km) et paraît augmenter vers l'Est.

Au voisinage du point d'explosion, deux laboratoires de prospection séismique ont enregistré de nombreux trains d'ondes réfléchies dont une partie s'explique sans doute par des réflexions multiples sur un miroir, qui pourrait être la partie supérieure du socle cristallin ; il est possible aussi que les séries réfléchissantes vers 9,8 s et 10,7 s proviennent de miroirs profonds.

Les résultats préliminaires des expériences relatées ci-dessus ont fait l'objet d'une communication présentée par M. Pierre Tardi au nom de l'ensemble des participants (P. Tardi, Expériences séismiques dans les Alpes occidentales en 1956; résultats obtenus par le « Groupe d'Etudes des Explosions Alpines », *Comptes rendus des séances de l'Académie des Sciences*, t. 244, p. 1114-1117, Paris, 1957).

Le texte complet de la communication est destiné à paraître dans les *Annales de Géophysique*.

Prof. Gutenberg: The relatively shallow Mohorovičić discontinuity also found in the Northern Alps by Reich, is probably connected with lower density, including a greater thickness of the « granitic » layer.

Prof. Hess : Commenting on the last and several preceding papers, as a geologist, might I say that the assumption of something so simple as a two-layered crust is quite outrageous.

The session is closed.

EXTRA SESSION

SATURDAY, SEPTEMBER 7 (afternoon)

Program

Discussion concerning seismic recording of an announced atomic bomb explosion in Nevada.

Although this is an extra, private session, outside of our Association, it seems desirable to put it on permanent record by giving here a brief summary of the discussion.

The session is opened at 02.00 p.m. with *President Bullen* in the chair in the presence of a large audience.

Prof. Bullen reads the following telegram from the Atomic Energy Commission, transmitted by the Division of Earth Sciences, 2101 Constitution Avenue, Washington 25, D. C. (National Academy of Sciences, National Research Council):

The Atomic Energy Commission has released the following information to the Division for transmittal to seismologists.

« The underground nuclear detonation is scheduled for 10 a.m. Saturday, Sept. 14, plus or minus two minutes. If there is any delay longer than two minutes, the firing will be postponed for 24 hours.

« Yield is expected to be in the range of one to ten kilotons of explosive force. Placement will be at the end of a multidirectional 2,000-foot tunnel into the side of a small mountain near northwest corner of Nevada Test Site. Detonation chamber is approximately 800 feet below ground surface, a depth sufficient to contain all radioactive material, thus eliminating any airborne radiation and any fallout problem. The experiment is intended to prove out this new method of testing as well as to test new instrumentation systems that are necessary.

« Placement is at the following location, using coordinates of the Nevada State grid system north 890,600, east 635,000. »

Prof. Bullen emphasizes importance that seismologists follow up the operation by preparing for recording of the explosion.

Dr. Willmore gives a general discussion of explosion recordings, including relationship to an explosion at Ripple Rock.

In the following discussion by *Prof. Bullen* and others it is agreed that travel time data are most needed in the range 15°—23°.

Dr. Carder : The USCGS recorded Nevada nuclear explosions up to 12° and somewhat beyond that, and Pacific explosions on islands up to 21° and elsewhere far beyond that. For Sept. 14 we will have a Benioff vertical in Mammoth Cave, Kentucky, at about 23°, a spread of HTL (Houston Technical Laboratories) 2 c/sec refraction equipment in Missouri at 18°—19°, 2 or 3 teams elsewhere at 20° or closer. In addition, Geo. Woollard will have a team somewhere in Mexico, and James T. Wilson will operate a spread in Michigan. There will also be the routine stations at St. Louis (Reef) at 20°, Little Rock (Reef) ca 18°—19°, Fayetteville (Benioff) at 17.4°, Dallas, Hungry Horse, Boulder, Rapid City and others, all within ca 16°.

In reply to questions by Prof. Bullen and others, Dr. Carder says this explosion should be a lot bigger than the others, which were shallow or airbursts.

Dr. Willmore, summing up the possibilities for recording, says that we can cover any desired part of the range 27° ± 3°. U.S. can cover out to about 20°. He further suggests a small, private committee, consisting of Dr. Hodgson, Mr. Mayer, Dr. Carder, and Prof. Press, to arrange for recordings in the best possible way.

The session is closed.

Later, on September 10, the Atomic Energy Commission released the following, additional information :

The Atomic Energy Commission has released this additional information on an underground nuclear detonation to the Earth Sciences Division for transmittal to seismologists :

« The Nevada Test Organization announced today that the date for the underground nuclear detonation (code named Rainier) has been changed from September 14 to September 18. The NTO also provided the following additional data essential to studies to be made by seismologists and geophysicists in the U. S. and other countries.

« 1. Yield, as before, is expected to be in the range of one to ten kilotons of explosive force.

« 2. Placement of detonation chamber : at the end of a horizontal, multi-direction 2,000 ft. tunnel dug into the side of a mesa at the extreme northern end of the test site. The chamber is 800 ft. below the top surface of the mesa.

« 3. Exact location of the chamber : Latitude 37°11.7'N, Longitude 116°12.2'W; altitude 6611.43 ft. (mean sea level).

« 4. Seismic signal data based on studies of above-surface shots in the current series — seismic waves from 10 to 150 miles from

NTS : body waves from 0.10 seconds to 0.4 seconds with periods of about 0.2 seconds predominating and surface waves of 0.3 to 1 second and greater. Periods produced by the Rainier test are expected to be comparable. The instrumentation used was not suitable for recording waves having periods greater than one second. Those interested in information concerning more distant locations are advised to contact the U.S. Coast & Geodetic Survey in Washington, D. C.

« 5. Detonation time on September 18 will be 17 hours Greenwich Mean Time plus or minus 2 minutes. If there is any delay longer than 2 minutes the firing will be postponed for 24 hours. »

According to information on USCGS epicenter card No. 79-57 the nuclear explosion took place on September 19 at 17.00.00 GMT at 37.2°N, 116.2°W in Nevada. *Dr. Carder* (private communication) says that, with one exception, all results were negative beyond 18°. The exception is College, Alaska, which recorded nearly all of the larger Nevada tests.

SEVENTH SESSION

MONDAY, SEPTEMBER 9 (morning)

Program

9.— Scientific communications : Physico-Chemical Interpretation of the Terms Magma, Crust, and Sub-Stratum.

This session is held jointly with the Association of Volcanology. It is opened at 09.00 a.m. with *Prof. Rittmann* in the chair. The complete proceedings of this session will be published by the I.A.V.

EIGHTH SESSION

MONDAY, SEPTEMBER 9 (morning)

Program

9.— Scientific communications :

A) Instruments.

41.— *H. Benioff :* A Reluctance Seismograph for Ultra Long Period Waves.

42.— *H. Benioff* and *F. Press :* New Results from Long Period Seismographs.

43.— *H. Benioff :* Ink-Writing Tidal Strain Recorder for Fused Quartz Extensometers.

44.— *T. C. Richards :* The Evolution of the Geophone.

45.— *P. L. Willmore :* A New Method of Calibrating Electromagnetic Seismographs.

B) Microseisms.

46.— *H. M. Iyer :* A Study of the Composition and Direction of Arrival of Microseisms.

47.— *J. Darbyshire :* Refraction of Microseisms on Approaching Island Stations.

48.— *D. S. Carder* and *R. A. Eppley :* Hurricane Microseisms in the Western Atlantic.

49.— *F. I. Monakhov :* Development of the Microseismic Method of Tracing Storms at Sea.

50.— *P. N. S. O'Brien* and *T. F. Gaskell :* Observation and Analysis of Microseisms in the Frequency Range 1—500 c/sec.

51.— *J. N. Nanda :* A Proposed Mechanism of Generation of Microseisms.

52.— *H. Jensen :* On the Beat-Distribution in Group-Microseisms.

The session is opened at 09.10 a.m. with *Dr. Båth* in the chair.

9. Scientific communications :

A) Instruments

41.— Prof. Benioff presents his paper on A Reluctance Seismograph for Ultra Long Period Waves.

The new instrument represents a modification of the earlier design of the variable reluctance transducer seismograph. The inertia reactor is cylindrical in shape and has a mass of 100 kg. It is supported by a centrally positioned alloy spring. In place of the six constraining ribbons of the earlier design, the new form uses a Willmore type suspension with consequent substantial reduction in the horizontal dimensions. In order to reduce the response to barometric pressure variations, the pendulum is supported by a central hollow cylindrical column surrounding the spring and the entire instrument is housed in a stiff cylindrical steel chamber. The pendulum period is adjusted to approximately 2 seconds. The transducer winding has a resistance of 135,000 ohms. The galvanometer, designed by F. E. Lehner, has a period of approximately 10 minutes and a critical damping resistance of approximately 135.000 ohms. In order to reduce the response to short period waves the transducer output is shunted with a condenser of 200 microfarads capacity and this is followed by a 135,000 ohm series resistor to the galvanometer. With the condenser and series resistor removed, the response of the seismograph to ground particle velocity is constant to within ±3 db for wave periods from 2 to 6000 seconds. With the condenser and resistor connected, the response is constant with respect to ground particle displacement within the same limits and over the same range of periods. Over the flat portion of the response characteristic, the magnification is approximately 40.

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

42. — Prof. Benioff presents the paper by *H. Benioff* and *F. Press* on New Results from Long Period Seismographs.

The following long period instruments have been in operation at the Seismological Laboratory for almost a year: (1) a modified

Benioff vertical reluctance seismometer, To = 2 sec, Tg = 180 sec, (more recently Tg = 600 sec) ; (2) Press-Ewing vertical and EW seismographs, To = 30 sec, Tg = 90 sec. For wave periods greater than several minutes the responses are approximately the same, whereas for waves shorter than 30 sec the response of the Benioff instrument falls off more rapidly due to a shunting capacitor. Using both types of instruments the following results have been achieved : (1) mantle Rayleigh waves and G waves are recorded frequently from earthquakes with magnitudes as small as $6\frac{1}{2}$—7 ; (2) the gap in the dispersion curve connecting crustal and mantle Rayleigh waves has been filled ; (3) relatively long period body wave pulses (T » 30 sec) are clearly observed owing to the reduced response to the shorter period, continuing earthquake motion ; (4) the impulsive initiation of the Rayleigh waves corresponding to the components of maximum group velocity is now frequently observed with a characteristic appearance which serves to identify the wave group at sight.

The complete paper will appear in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.* See also *The Geophysical Journal,* Vol. 1, pp. 208-215, 1958.

Prof. Byerly : Does the new variable reluctance seismometer operate in a partial vacuum.

Prof. Benioff : Yes.

43. — *Prof. Benioff* presents his paper on Ink-Writing Tidal Strain Recorder for Fused Quartz Extensometers.

A new recording system having high sensitivity and excellent stability characteristics has been developed for recording tidal strains and long-period earthquake waves with the fused quartz extensometer. The system uses a fixed carrier frequency of 5 mc, coupled to two resonant circuits having tuning capacitors formed by a plate attached to the end of the quartz tube and two fixed plates. The resonant circuits are coupled to crystal diode rectifiers whose output drives a Rectiriter inkwriting recorder. Two forms are being tested in our Dalton and Isabella installations. In the Isabella installation the oscillator employs a vacuum tube. In the Dalton installation the oscillator is driven by transistors and the rectified output current is coupled to a triple push-pull transistor cathode-follower circuit devised by L. Blayney, and this drives the Rectiriter recorder. The all transistor circuit version operates for several months on a set of dry cells and is thus entirely independent of the power line.

The complete paper will probably be submitted for publication in the *Bulletin of the Geological Society of America.*

Dr. De Bremaecker : It is said that elastic effects of surface temperature variations are not always negligible. What do you find in your records ?

Prof. Benioff : Our shallow tunnel at Dalton Canyon shows an elastic response to surface temperature fluctuations.

Prof. Coulomb : A quelle profondeur serait-il nécessaire de placer l'extensomètre en pays plat ?

Prof. Benioff : This is also a question of economy. But it seems desirable to reach a depth of 100 meters.

Dr. Oliver : How is the motor which balances the condensor controlled ?

Prof. Benioff : By two push buttons located near the recorder.

Prof. Tsuboi : How long had you to wait until you could get satisfactory records after you had finished the installation ?

Prof. Benioff : Approximately 9 months.

Dr. Båth states in conclusion that the extension towards longer periods marks a new development in seismology, the importance of which cannot be overestimated. We are all impressed by the outstanding developments in instrumental seismology achieved in Pasadena under the leadership of Prof. Benioff.

44. — Dr. Richards reads his paper on The Evolution of the Geophone.

L'auteur passe en revue l'évolution du géophone à partir des séismoscopes primitifs et des séismomètres mécaniques à déplacement jusqu'aux séismographes transmetteurs d'aujourd'hui (séismographe électrodynamique à mesure de vélocité, séismographes faisant appel à la piézoélectricité ou à la magnétostriction). Le géophone utilisé pour l'exploration géophysique a été grandement perfectionné surtout après la première et la seconde Grande Guerre grâce aux progrès marqués que l'on a faits dans le domaine de la métallurgie, de l'électronique et des matières plastiques. On a ainsi mis au point les appareils de plus en plus efficaces qui trouvent un nombre croissant d'applications spécialisées sur terre et sur mer, dans les trous de sonde ou au cours d'expériences faites sur modèles. Sur terre, le géophone à bobine mobile est surtout employé, mais sur mer et dans les trous de sonde, le modèle qui enregistre les pressions est au premier plan. Dans cette dernière catégorie, le cristal de céramique trouve des emplois de plus en plus nombreux. Le géophone que l'on emploie aujourd'hui dans les trous de sonde favorise de façon remarquable le perfectionnement de la méthode de réflexion vu qu'il permet la mesure des vitesses dans des couches de roches minces.

Les recherches faites en vue d'améliorer le géophone portent sur des points tels que ceux-ci ; mise au point de géophones sacrifiables, de géophones pouvant faire corps avec les conduites électriques de façon qu'il ne soit plus nécessaire de les placer un par un à l'endroit voulu, de radio-géophones devant servir aux levés par réfraction, etc. On s'efforcera également d'améliorer le transmetteur à céramique et d'en tirer encore mieux parti.

The complete text (in English) of this paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Dr. Carder : Has a marine geophone been developed to operate at depths of 150 meters, more or less, and sensitive to surface fluctuations of a foot or so ?

Dr. Richards : At that depth it is relatively insensitive, but one can be developed to respond to that fluctuation.

Prof. Byerly also takes part in the discussion.

45. — *Dr. Sutton* reads the paper by *P. L. Willmore* on A New Method of Calibrating Electromagnetic Seismographs. The following summary has been given the title Emploi du pont d'impédances pour l'étalonnage des séismographes électromagnétiques.

On procède à l'étalonnage en intercalant le séismomètre dans le circuit d'une des branches du pont d'impédances Maxwell et en plaçant le galvanomètre aux bornes de la sortie. On fait circuler dans le pont un courant alternatif à basse fréquence et on y établit l'équilibre, le séismomètre étant immobilisé. Quand on libère le séismomètre, le galvanomètre se met à décrire des arcs égaux à ceux qui tireraient leur origine d'une accélération d'origine terrestre proportionnelle au courant qui circule dans le pont. Pour déterminer la constante de proportionnalité, on applique une force électromotrice de substitution aux bornes du bras de proportion du pont. La méthode permet également de déterminer l'action du galvanomètre sur la masse du séismomètre. L'article comprend un certain nombre de courbes typiques d'étalonnage de séismomètres Benioff, Sprengnether et Willmore.

Dr. Hodgson : I am grateful to Dr. Sutton for presenting this paper in the unavoidable absence of Dr. Willmore. — The device which the paper describes permits a technician to calculate all the electromagnetic instruments of a station in a few hours. We propose to publish magnification curves for all Canadian stations in our bulletins ; the first group, of three stations, will appear in the bulletin of the first quarter of 1957.

Prof. Benioff : The method assumes that the mechanical system is simple and has only one degree of freedom. Many instruments, particularly long-period pendulums, do not conform to this requirement. These must be subjected to actual shaking table tests.

B) Microseisms

46. — *Dr. G. E. R. Deacon* gives a summary of the paper by *H. M. Iyer :* A Study of the Composition and Direction of Arrival of Microseisms.

The main aim of this investigation is to track storms in the Atlantic by using microseisms generated by them. Four different storms are chosen and storm bearings estimated every three hours by measurement of the correlation coefficients between the vertical and horizontal components, and the intensities of the horizontal components. The microseismic records from Kew Observatory were used for the study. The ratio of Rayleigh/Love wave intensity, and its variation with the direction of arrival shows some interesting features. The evaluation of the Rayleigh wave constant (ratio of horizontal/vertical component of Rayleigh waves) suggests a new and simpler approach to microseismic direction finding.

The complete text has appeared under the title : A Study on the Direction of Arrival of Microseisms at Kew Observatory, *The Geophysical Journal,* Royal Astronomical Society, London, Vol. 1, No. 1, pp. 32-43, 6 Figs, March, 1958.

47. — *Dr. G. E. R. Deacon* gives a summary also of the paper by *J. Darbyshire :* Refraction of Microseisms on Approaching Island Stations.

If it is assumed that microseisms are surface waves between the ocean and the sea bed of the type first described by Stoneley, then the shallower the water, the greater the wave velocity, and refraction will occur due to the changing ocean depths. Using the figures based on this assumption given by Longuet-Higgins, refraction diagrams were drawn for 6s. waves approaching Bermuda for every 30° interval of direction, starting with 0°. The diagrams showed a change of direction up to 35° in some cases and also a marked reduction of intensity in certain directions, particularly 30°, 60°, 120° and 150°. This effect would explain why some storms are more effective than others of similar intensity in producing microseisms at Bermuda.

Similar refraction diagrams were prepared for the western approaches to the British Isles for 6s. microseisms approaching from SW, WSW, W, WNW and NW directions, and for 4s. and 8s. waves approaching from the W direction. The diagrams showed that the deviations varied from 7° for WSW to 26° for WNW, and that the intensity of microseisms approaching from the W direction were much reduced. This was confirmed by examination of the variation of the intensity of the vertical component of microseisms due to sixteen moving storms during the period 1945-1953, which were on a westerly bearing to the British Isles at one stage in their track.

The complete text appears in two papers :

1) J. Darbyshire : Refraction of Microseisms at Island Stations, *Mon. Not. R. Astr. Soc., Geophys. Suppl.,* Vol. 7, No. 3, pp. 147-152, 4 Figs, London, December, 1955.

2) J. and Mollie Darbyshire : The Refraction of Microseisms on Approaching the Coast of the British Isles, *Mon. Not. R. Astr. Soc., Geophys. Suppl.,* Vol. 7, No. 6, pp. 301-307, 4 Figs, London, November, 1957.

Dr. Båth : I find the study of refraction of microseisms on approaching coasts very interesting, as I have been studying the same problem in Scandinavia a few years ago.

48. — *Dr. Carder* reads the paper by *D. S. Carder* and *R. A. Eppley :* Hurricane Microseisms in the Western Atlantic.

The U. S. Navy closed its hurricane microseismic program early in 1956 after 12 years of operation. A preliminary review of the data collected during operation lends support to many earlier ideas on the generation and transmission of microseisms and tends to refute others. There is some evidence that the weaker microseisms may originate from a hurricane area when it is at some distance off shore, but the stronger ones most probably have near the shore sources. Attenuation over eastern North America is low, and relatively high along the continental margins. The microseismic technique may be a tool to detect the presence of a hurricane in the general area, especially useful in certain isolated areas where other means are not available.

Reference is made to the following two papers by D. S. Carder : Transmission of Microseisms Across North America and the Western North Atlantic, *Trans. Amer. Geophys. Union,* Vol. 36, No. 5, pp. 838-842, 3 Figs, October, 1956.

Microseisms at Bermuda. *Trans. Amer. Geophys. Union,* Vol. 36, No. 5, pp. 843-854, 6 Figs, October, 1956.

Prof. Press : Have cases occurred where large sea waves are recorded without being accompanied by microseisms ?

Dr. Carder : Yes. There are cases of large waves without corresponding microseisms. However, the correlation coefficient, as Mr. Eppley states, is from 0.62 to as high as 0.88.

Father Ingram : Do you have a good correlation between the periods of the sea waves and microseisms ? Are they in ratio 2 : 1 ?

Dr. Carder : We do have such a correlation, but it is very rough.

49.— The paper by *F. I. Monakhov,* Development of the Microseismic Method of Tracing Storms at Sea, is read only in title in the author's absence.

Numerous investigations of microseisms made by scientists of different countries show that there is undoubtedly an interconnection between microseismic and cyclonic activities over the sea surface. An important contribution to recent investigations are new methods of determining the locations of microseismic sources. Positive results of these investigations made it possible to begin a more detailed study of the conditions under which microseisms originated.

It should be noted that many problems related to the methods of determining the directions of microseisms and the conditions under which they occur, are either a blank spot, or not studied sufficiently. Great efforts are still needed to make the microseismic method of tracing storms at sea practically useful and effective.

This report contains some results on the analysis of microseismic observations conducted in the Soviet Union for the last five years. The following problems are touched in the report :

1) accuracy of determining the directions of microseisms by the method of a tripartite station ;

2) the development of the method to determine the microseismic directions by the method of phase transitions ;

3) the nature of particle motions in microseismic waves and revealing of Rayleigh and Love waves to use them in determining the directions of microseisms ;

4) synoptical conditions under which microseisms occur ;

5) the location of a microseismic source with respect to the cyclone centre.

The following conclusions have been arrived at :

1. The method of a tripartite station gives the best results if the distances between seismographs are no less than 2.5—3 km. But even under this condition a strong dissipation in some directions is observed.

2. An accuracy increase in determining the microseismic directions as against the accuracy of the tripartite station can be effected by making the bases longer. The recording of microseisms should thus be made not with three but with a large number of seismographs.

3. Motions of the Earth's particles in microseismic waves as observed on Kamchatka and in the Crimea are of a rather complex character. Rayleigh and Love waves are singled out in rather rare cases, and the directions of their arrivals to the observation point are far from the direction to the microseismic source. Therefore the practical use of the method of determining the directions to the microseismic source based on the registration of Rayleigh or Love waves meets some difficulties.

4. Microseisms originate when the cyclone centre and its fronts are passing over the sea surface. The cold front as against the warm one, and that of occlusion, are a more intensive microseismic source. The strongest front microseisms are linked with a part of the cold front nearest to the cyclone centre.

5. Intensity of microseisms grows with a pressure fall in the cyclone centre but with a lag by about 8—12 hours. Due to this reason, sources of microseisms lag behind the cyclone centre by approximately 10 .V km, where V is the velocity of the cyclone movement in km per h.

The complete text has been submitted for publication in *Publications du Bureau Central International de Séismologie, Série A, Travaux Scientifiques, Fasc. N° 20.*

50. — *Dr. O'Brien* presents the paper by *P. N. S. O'Brien* and *T. F. Gaskell* on Observation and Analysis of Microseisms in the Frequency Range 1-500 c/sec.

Paper and magnetic tape recordings were made of the microseismic background due to natural (wind, rain, etc.) and artificial (vehicles, animals, small explosion, etc.) sources. Six channels were recorded simultaneously and each record usually lasted a few minutes. The detector was normally a Willmore velocity sensitive geophone but sometimes an accelerometer was used. Usually four channels recorded the vertical motion and two the horizontal motion. The minimum ground motion detectable was about 10^{-8} cm/sec.

Amplitude-frequency spectra were obtained for varying lengths of record by playing the magnetic tapes back through narrow band filters. Under quiet conditions the amplitude fell rapidly at frequencies above about 20 c/s, but was usually still measurable at about 100 c/s.

Comparisons were made of the different components of ground motion at a single station, and of the same component at different stations. No coherent wave patterns were found except for well localised sources.

Care was always taken to plant the detectors as firmly and as similarly as possible, but even so it was often found that stations only 10 or 20 feet apart gave amplitudes which differed by up to 50%.

This paper has not yet been submitted for publication.

Dr. Carder : Have you given thought to burying a geophone in an attempt to get rid of noises caused by rain, wind, etc. ?

Dr. O'Brien : Yes, but we have not acted on it.

51. — The paper by *J. N. Nanda,* A Proposed Mechanism of Generation of Microseisms, is read only in title in the author's absence.

Microseisms produced at sea have been ascribed to various causes, namely, selection of suitable periods from a broad noise band by long oceanic paths, second order pressure effects of standing waves or pounding of surf on steep coast-lines. But the observations may point to an all embracing cause involving winds, waves, and special orientation of winds either involving circular wind currents or such winds as will pile up or deplete water near a steep coast-line. Such changes of sea level will pulsate with the auto-correlative periods, if any, in eddy viscosity near the surface of the sea which in turn depends on sea roughness. If there happen to be standing waves, the roughness and, therefore, the eddy viscosity will have a period half that of waves, but in this process, standing waves are not necessary for generation of microseisms. In many observed instances the prominent microseisms have less period than half of the period of prevailing sea waves.

The complete text will appear in *Publications du Bureau Central International de Séismologie, Série A, Travaux Scientifiques, Fasc. N° 20.* See also J. N. Nanda : A Review of Research on Microseisms, *Defense Science Journal,* Vol. 4, p. 19, 1954.

52. — The paper by *H. Jensen,* On the Beat-Distribution in Group-Microseisms, is read only in title in the author's absence.

In many stations — such as the Danish station Scoresby Sund on the eastern coast of Greenland — the microseisms most frequently show the grouping-phenomenon. The usual description by stating the character, the mean period, and the average maximum amplitude does not give full information of the phenomenon. Therefore an attempt is made to give a statistical description by studying the distribution of the beat-interval τ, a beat being defined as a swing in the record which is greater than both adjoining swings. Accordingly τ is not the same quantity as the « Schwebungsdauer » studied by Kohlbach.

For Scoresby Sund the result of the investigation is that in spite of great differences we always find a logarithmic normal distribution. The variance of the distribution varies very little and consequently the variation with the time may be described by variation in the mean only. By pure group-microseisms it is shown that the simple mean of τ is proportional to the period of the carrier wave.

For Köbenhavn where the microseisms most probably are of a mixed oceanic and coastal origin we find the same distribution law but no proportionality to the carrier period.

A study of the difference between the horizontal and the vertical records shows that τ as a rule is greater on the vertical instrument. This is found too by a microseismic storm in Köbenhavn during which the three instruments (Galitzin 12 sec) had the same set of constants. This may be explained by assuming the existence of a comparable Love-component in the microseisms.

Reference :

Henry Jensen : On the Beat-Distribution in Group-Microseisms. Geodaetisk Institut, Meddelelse No. 34, 27 pp., 17 Figs, Köbenhavn, Danmark, 1957.

Dr. Båth : In conclusion, we note that the discussions on microseisms are much milder now than a few years ago. It seems to me that new lines of attack on the whole problem are very desirable now. In this connection I am looking upon the investigations of wave propagation over continental and oceanic paths as very essential for the understanding of the distribution of microseisms.

The session is closed at 11.35 a. m.

NINTH SESSION

MONDAY, SEPTEMBER 9 (afternoon)

Program

9.— Scientific communications : Geochronology and Radioactivity.

53.— L. T. Aldrich, G. R. Tilton, G. W. Wetherill, and *G. L. Davis :* Radioactive Ages of Rocks.

54.— G. W. Wetherill, L. T. Aldrich, and *G. L. Davis :* Potassium-Argon and Rubidium-Strontium Age Measurements.

55.— S. S. Goldich, H. Baadsgaard, and *A. O. Nier :* Investigations in A^{40}/K^{40} Dating.

56.— P. M. Hurley : Progress Report on A/K and Sr/Rb Age Measurements.

57.— A. A. Polkanov and *E. K. Gerling:* K-A and Rb-Sr Methods and Age of Precambrian of the USSR.

58.— A. A. Smales, R. K. Webster, and *J. W. Morgan :* Some Recent Harwell Analytical Work on Geochronology.

59.— J. M. López de Azcona: Consideraciones Geocronológicas del A^{40}.

60.— J. M. López de Azcona: Relación Atómico de Niobio y Tántalo en la Provincia de la Coruña.

This symposium, which is held jointly with the Association of Volcanology, has been organized by *Prof. Russell.* The session is opened at 02.00 p. m. with Prof. Russell in the chair.

9. Scientific communications: Geochronology and Radioactivity

53.— L. T. Aldrich, G. R. Tilton, G. W. Wetherill, and *G. L. Davis:* Radioactive Ages of Rocks.

The experience of the group at the Carnegie Institution of Washington in the measurement of K-A, Rb-Sr, Th-Pb and U-Pb ages is summarized. It is concluded that reliable ages are obtained most regularly from pegmatitic uraninites. K-A and Rb-Sr ages of micas from granites and pegmatites usually agree with each other but the occurrence of large differences in these two ages indicates the need for measuring both. U-Pb and Th-Pb ages of microlites, zircons, monazites, and columbite-tantalites are so variable that their usefulness as anything but an indication of the age is questioned.

54.— G. W. Wetherill, L. T. Aldrich, and *G. L. Davis:* Potassium-Argon and Rubidium-Strontium Age Measurements.

K-A and Rb-Sr ages have been measured on samples from the U.S.A. and Canada. In many regions almost all of the K-A and Rb-Sr ages agree with one another and this age is interpreted as the age of the last mineralization. In one region (Sudbury, Ontario) the K-A and Rb-Sr ages do not usually agree, and in this case a unique interpretation cannot be given at present.

The southwestern U.S.A. granitic rocks 1350±100 million years ago are found over a large area. It is thought that these rocks were formed during an orogenic period at this time. Similarly, in the Appalachians the K-A and Rb-Sr ages have been found to agree at around 350 million years and in the Grenville at 1000 million years.

In the Sudbury region many ages have been measured in the region between the area of 1000 million year old Grenville rocks and the 2600 million year rocks about 200 miles to the north. Here the Rb-Sr and K-A ages do not usually agree. The only conclusion which seems certain is that these rocks are all greater than 1000 million years of age and that at least one period of igneous activity and metamorphism between 2600 and 1000 million years occurred in this region.

Dr. Rutten: In view of the mobility of K and Na, it seems to be better in discussing K/A ages to use the parameter: « Argon losses seem to be x % greater than Potassium losses », instead of: « Argon losses seem to be $(100 - x)\%$ ».

Prof. Houtermans: I should suggest to call « concordant » Pb-ages only those in which Pb^{207}/Pb^{206}-age is also in agreement with

Pb^{206}/U^{238}-age and Pb^{207}/U^{235}-age. Agreement of the latter two ages in cases of minerals considerably younger than 1000 mill. years does not always give the right age, because U- or Pb-loss in these cases affects the chemical ages in the same manner, while Pb^{207}/Pb^{206}-age is considerably less affected by loss of either of these elements.

Sir Harold Jeffreys : Holmes has suggested that lead in a uranium mineral forms lead uranate, which is very insoluble.

Mr. Aswathanarayana points to the discrepancy between U-Pb and Th-Pb ages. He further suggests dating feldspar or muscovite, using lead, K-A, and Rb-Sr methods together.

55. — *S. S. Goldich, H. Baadsgaard,* and *A. O. Nier :* Investigations in A^{40}/K^{40} Dating.

In connection with a project to date a large number of rocks in the Lake Superior region, a number of potassium-bearing minerals and rocks have been studied with reference to their potential use in geologic dating. The A^{40}/K^{40} ratios of cogenetic mica and feldspar were investigated, and in a group of unaltered granites and granitic gneisses ranging in age from 500 to 2500 million years, the feldspars show a relatively constant argon deficiency of 36 per cent compared to the micas. Thermal alteration of granite, however, may affect biotite to a greater degree than the associated feldspar, and in areas where thermal history subsequent to the initial crystallization is suspected, dating of both feldspar and mica may be particularly useful. Replicate determinations on crushed feldspar (40-60 mesh) showed no measureable leakage of argon over a period of 4-12 months. Five determinations of A^{40}/K^{40} for the Dickinson County, Michigan microcline show a maximum deviation of 4 per cent ; the first and last determinations, a year apart, differ by less than 3 per cent. Stilpnomelane samples proved to be useless for dating. A series of samples representing progressive metamorphism from slate to phyllite to schist to coarse gneiss gave concordant A^{40}/K^{40} ages, and fine-grained sericitic materials have been used to advantage for dating an orogeny in central Minnesota.

The complete text has been published in the *Trans. Amer. Geophys. Union,* Vol. 38, No. 4, pp. 547-551, 2 Figs, August, 1957. See also H. Baadsgaard, S. S. Goldich, A. O. Nier, and J. H. Hoffman : The Reproducibility of A^{40}/K^{40} Age Determinations, *Trans. Amer. Geophys. Union,* Vol. 38, No. 4, pp. 539-542, August, 1957.

Prof. Folinsbee : Your Duluth Gabbro age (1.1 x 10^9 years) implies a greater age for the relatively unconsolidated Keweenawan flows and sandstones which it intrudes. What age do you get for the Post Keweenawan (Killarney) intrusives ?

Prof. Goldich : 0.8 to 1.0 x 10^9 years for granophyres.

Mr. Wetherill : While it is certainly possible that pegmatites may be formed at other times than the associated granites, do you have any empirical evidence from your age measurements that this is the case ? In the younger rocks the age of the pegmatites seems to be the same as for the granite.

Prof. Goldich: We have made two A^{40}/K^{40} determinations on Frenconia glauconite. Our ratios agree closely with that of Wasserburg et al, and we calculate this as Cambrian.

56.— P. M. Hurley: Progress Report on A/K and Sr/Rb Age Measurements.

Comparisons between A/K and Sr/Rb age measurements indicate general agreement except in certain localities. Disagreement is believed to be due to metamorphic effects rather than primary argon, weathering, or analytical errors. In general, however, the agreement between these methods is notable. Metamorphic rocks appear to reflect a homogeneous age for a belt similar to that given by rocks of plutonic character. Potash feldspar commonly shows Sr/Rb ages similar to micas, but this is not the case with A/K ratios. A/K ages on detrital minerals in sediments provide interesting information on the source of the minerals. Deep ocean sediments appear to have retained the original age ratios of the detrital material.

This paper is a progress report on age measurements made in the Department of Geology and Geophysics of Massachusetts Institute of Technology, and it has not been published. The material will be published at various times in the future as it is completed, and probably in various journals.

Prof. Urey: Gerling and Levskii have shown that primitive helium, neon, and argon were included in a stone meteorite, and gave evidence indicating that this occurred when the meteorite was melted. It would be well to make experiments on the retention of argon by melted silicates in connection with the possible retention of argon during recrystallization of igneous rocks. This might explain the potassium-argon ages which are greater than the rubidium-strontium ages.

Prof. Wasserburg questions the value of A^{40}/A^{36} obtained. In general it is necessary to measure this ratio in order to determine the radiogenic argon content of minerals. We must be careful in the analytical procedures used in age dating if we want to obtain credible data.

Mr. Wanless: Wetherill et al report Wauy Lake granite as about 1000 mill. years with a check between K/A and Rb/Sr. Hurley reports approx. 1400 mill. years for Wauy Lake also with a check between the two methods.

57.— A. A. Polkanov and *E. K. Gerling:* K-A and Rb-Sr Methods and Age of Precambrian of the USSR.

See *Trans. Amer. Géophys. Un.*, Vol. 39, pp. 713-715, 1958.

58.— A. A. Smales, R. K. Webster, and *J. W. Morgan:* Some Recent Harwell Analytical Work on Geochronology.

Rubidium and strontium determinations made by the method of stable isotope dilution have been used to obtain values for the ages of two of the international inter-comparison suite of lepidolites, Bikita Quarry, So. Rhodesia and Pala Mine, So. California, and two lepidolites from Hombola, Tanganyika. The rubidium-strontium ratios of the two meteorites Forest City, a chondrite, and Johnstown, an achondrite, differ by a factor of about 5, so that rubidium and strontium determinations combined with the isotopic analysis of the strontium extracted from each meteorite permit a calculation of the meteoritic age.

Neutron activation analysis is an alternative technique that has been used for rubidium determinations and it is useful to have the supporting evidence that is provided by the usually close agreement between these results and those found by isotope dilution analysis.

A brief mention will also be made of the determination of lead in small samples of monazites by direct polarographic analysis.

A more complete text has appeared in the *Trans. Amer. Geophys. Union,* Vol. 38, No. 4, pp. 543-546, August, 1957.

59. — *J. M. López de Azcona :* Consideraciones Geocronológicas del A^{40}.

Se efectúa un balance del K^{40} y del A^{40} contenidos en la atmósfera, hidroesfera, litoesfera y manto. Se efectúan una serie de consideraciones sobre la relación de los dos tipos de evolución del K^{40}, así como de sus períodos de semidesintegración y se llega a las seis conclusiones que se discuten en la comunicación.

The complete text will appear in *Revista Notas y Comunicaciones del Instituto Geológico y Minero,* Vol. 48, 1957.

60. — *J. M. López de Azcona :* Relación Atómico de Niobio y Tántalo en la Provincia de la Coruña.

Durante los años 1955 y 1956 se efectuaron unos estudios detenidos de las reservas de niobio y tántalo de las zonas de Boiro y Noya, respectivamente. Se ideo una técnica para las valoraciones espectroquímicas de estos elementos y dieron como resultado los valores siguientes:

Zona de Boiro. — Valoración en 82 muestras. Relación atómica Nb/Ta-14,7.

Zona de Noya. — Valoración en 83 muestras. Relación atómica Nb/Ta-11,6.

The complete paper will appear in *Publications du Bureau Central International de Séismologie, Série A, Travaux Scientifiques, Fasc. N° 20.*

The session is closed.

TENTH SESSION

MONDAY, SEPTEMBER 9 (afternoon)

Program

9. — Scientific communications : Seismological Geography.

61. — *E. F. Savarensky :* Results of Seismic Investigations in the USSR.

62. — *G. P. Gorshkov :* On Seismic Intensity Regions of Asia.

63. — *F. Neumann:* Analysis of Earthquake Intensity Distribution Maps.

64. — *B. Gutenberg :* Effects of Ground on Earthquake Motion.

65. — *C. F. Richter :* The Form of Isoseismals.

66. — *N. Pinar :* Relations entre l'activité sismique et les grandes structures tectoniques de la Terre.

67. — *K. Wadati* and *T. Hirono :* On the Abnormal Distribution of Seismic Intensity.

68. — *S. V. Medvedev* and *B. A. Petrushevsky :* Methods and Experience in Dividing the USSR Territory According to Seismic Intensity.

The session is opened at 02.00 p.m. with *Prof. Richter* in the chair.

9. Scientific communications : Seismological Geography

61. — *Mrs. Dr. Kondorskaya* presents the paper by *E. F. Savarensky :* Results of Seismic Investigations in the USSR.

The results of the work performed by seismologists of the USSR Academy of Sciences and academies of sciences of the Union republics have been collected in a Seismicity Atlas of the USSR. It is based on the conclusions from the observations made by the USSR seismic stations during more than forty years.

An essentially new element of the Atlas maps as against the former ones is a uniform principle of dividing earthquakes in their magnitude and accuracy of determining epicentres.

The aim of the work is to compile uniform materials necessary in solving the following basic problems :

1) the study of the causes and conditions of earthquake occurrence ;

2) the checking of the map of the USSR seismic intensity.

One of the efficient methods in studying the causes and conditions of earthquake occurrence and elucidating the causes of tectonic processes is the correlation of the locations of geological and geomorphological elements and epicentres, account being taken of the earthquake magnitude. One more important factor here is the analysis of a territorial distribution of earthquake magnitudes which enables us to evaluate the field of potential energy of tectonic stresses.

The value of the Atlas in the schemes of the USSR seismic regions is that the knowledge of magnitude and relative energy of earthquakes as well as of the focal depth makes it possible to objectively estimate a relative energy flux to the surface of a medium possessing mechanical properties of the Earth's crust. Such a division into intensity regions, provided that proper corrections by geological and local ground conditions are made, will be more reliable than the former.

There are five main intensity groups of earthquakes:

Single, extremely strong earthquakes ($M > 7\frac{1}{2}$), catastrophic under the USSR conditions, are attributed to the first group.

The second group comprises earthquakes which caused or may cause serious destructions in a large space ($7\frac{1}{2} > M \geqslant 6\frac{1}{2}$). If the focus was in the Earth's crust, earthquake intensity reached 8—9 grades.

The third group comprises earthquakes which caused or can cause destructions and damages of buildings ($6\frac{1}{2} > M \geqslant 5\frac{1}{4}$). With the focus being in the Earth's crust their intensity reached about 7 grades.

These earthquake groups are of practical value. Deep-focus earthquakes of the same magnitude may not always be accompanied by destructions.

The last two groups, fourth and fifth, embrace, as a rule, non-destructive earthquakes ($5\frac{1}{4} > M \geqslant 4\frac{1}{4}$, $M \leqslant 4$).

The distribution of earthquakes into these two groups was made with allowance for the maximum distance in recording earthquakes. Data on weak earthquakes enable us to establish genetic relations between strong and weak earthquakes, in particular, to determine the dependence between the earthquake frequency and magnitude.

Epicentres were classified according to the accuracy of their determination. The first accuracy class (A) comprised epicentres with a possible error in determining the locations of not more than 25 km, which was possible if observations were made by the stations next to the epicentres. The second class (B) admitted the error less than 50 km. If the error was not determined the epicentres were considered to be non-class.

With regard to focal depth, earthquakes are divided into those inside the crust and under the crust. The latter require the indication of a focal depth.

The basic materials for the Atlas were catalogues and maps of seismicity zones (compiled from the catalogues): 1 — Carpathian Mts, 2 — the Crimea, 3 — the Caucasus, 4 — Copet-Dag, 5 — Altai, 6 — the Lake of Baikal, 7 — the Far East, 8 — the Arctic.

They include about 10,000 epicentres. A general seismicity map of the USSR has also been compiled.

It must be noted that there is irregularity in presenting seismicity in time. This refers mostly to weak earthquakes. A gradual increase in their frequency is accounted for by an increase in number and in sensitivity of instruments at seismic stations, which was especially evident during the last five-year period.

Investigations have shown that equal seismicity data for the USSR territory can be obtained only by the use of earthquake epicentres with $M > 5$.

During recent years permanent and temporary seismic stations of high accuracy and equipped with very sensitive instruments have been at work to find the causes of destructive earthquakes in the pleistoseist regions of the strongest earthquakes.

This served as the material for compiling additional, more detailed maps of such regions. Maps were compiled for the Akhalkalakskoye Nagorie, Shemakha region, Ashkhabad region, Northern Tien-Shań region, Garm region.

The complete text of this paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. No 20.*

Prof. Neumann : Can you associate many of these epicenters with known faults ?

Mrs. Kondorskaya : A seismic atlas is being published, which will describe the comparison of the epicenter locations with the geological map.

Prof. Benioff : Are these maps published and available ?

Mrs. Kondorskaya : Part is published and the rest is in press. The published part is in *Akad. Nauk SSSR, Trudi Geofis. Inst.,* No. 25 (152), Moscow, 1954.

62. — The paper by *G. P. Gorshkov,* On Seismic Intensity Regions of Asia, is read in title only.

1. The division of the territory into regions according to their seismic intensity is aimed at the receipt of data (for each given point) on the location and magnitude of expected earthquakes.

2. This task can be fulfilled only if a joint analysis of seismic and geological materials is made. It is not sufficient to have obtained only seismic data. Extrapolation is possible only when concrete seismo-tectonical relations are determined.

3. Among the materials of seismic statistics a great importance in the solution of the given problem should be attached to maps of isoseists, especially maps of epicentres with those parameters which are available due to the modern service and seismic observations.

4. Among the materials of a geological nature an important rôle in determining seismic intensity regions is played by geotectonical data.

5. A map of seismic intensity for the USSR territory was first compiled in 1937. The latest edition of the map was issued in 1957. The experience showed that the map of seismic intensity can be successfully used in the practice of earthquake-proof construction.

6. The map of seismic intensity for the territory of the Chinese People's Republic was compiled in China in 1956.

7. At present, an attempt may be made to compile similar maps for other Asian countries. To this end, seismologists and geologists concerned with this work should combine their efforts and set up a permanent commission on seismic intensity at the International Association of Seismology and Physics of the Earth's Interior of the International Union of Geodesy and Geophysics.

The complete text of this paper will appear in *Publications du*

Bureau Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.

63. — *Prof. Neumann* presents his paper on Analysis of Earthquake Intensity Distribution Maps.

When earthquake intensities (Modified Mercalli Scale of 1931) for a Washington State shock are plotted against epicentral distance, there is a minimum epicentral distance at which each grade of intensity is observed. The « lowest » intensities are provisionally designated basement rock intensities because they represent the lowest intensities obtained with respect to distance, and because their consistently uniform distribution in all earthquakes connotes transmission of energy through a very homogeneous medium. Intensities on the surface may be between four and five grades above these basement rock intensities.

This wide range of intensities due to local geological conditions was clearly pointed out in San Francisco in 1906 when engineers, who estimated the violence of the ground motion on the basis of damage done, concluded that the vibrations on made land were about 12 times more violent than on outcrops of serpentine rock. Since recent investigations of strong motion seismograph records (see « Earthquake Intensity and Related Ground Motion », by F. Neumann, 1954, Univ. Wash. Press) indicate that acceleration is doubled for each grade increase in the Modified Mercalli Scale, the figure 12 is consistent with the intensity range (between MM-4 and -5) quoted above.

The investigation just quoted also reveals that a single strong motion seismograph may register certain period-acceleration combinations that can be correlated with the intensity observed at the station site, while other period-acceleration combinations can be correlated with the intensity in the basement rock beneath the station. There is thus instrumental and non-instrumental evidence to support the concept of an observable and symmetrical distribution of intensity in basement rock and in basement rock outcrops. Similar evidence shows the presence of two types of basement rock in southern California that can be broadly correlated with regional tectonic structure. One type produces intensities consistently one intensity grade higher than the other.

Since investigations of shocks up to MM-8 show that when epicentral distance is doubled, the basement rock intensity drops one grade, a set of concentric circles can represent basement rock intensity distribution for a shock of any intensity. In practice, several such sets of circles (representing different maximum intensities) are drawn on transparent paper and placed over a map of observed intensities until a set is found on which the circles truly represent the minimum distances at which the various intensities are found. The common center of the circles is the epicenter. No change in intensity distribution due to varying focal depth has been found.

The complete paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

64.— *Prof. Gutenberg* reads his paper on Effect of Ground on Earthquake Motion.

Six identical seismographs have been operated at 25 locations in and near Pasadena to investigate effects of the ground on surface motion in earthquakes. On 200 to 400 m deep alluvium with the water table over 50 m deep, amplitudes are frequently five or more times as large as those at the Seismological Laboratory on rock, if the wave period is between 1 and 1 ½ sec. On Tertiary and on less than 100 m thick alluvium, the maximum ground response occurs for periods of ¼ to ½ sec. In areas with several km of sediments and the water table less than 50 m deep, amplitudes roughly five times those at the Laboratory are observed for all waves having periods of 0.2 to 7 sec. Relatively strong shaking lasts longer on alluvium than on rock, up to five times on ½ km deep alluvium. Appreciable differences in duration and amount of shaking are found even at sites less than one km apart. The importance of selecting rock or at least dry ground for foundations of buildings is stressed.

The complete paper has been published in the *Bulletin of the Seismological Society of America,* Vol. 47, No. 3, pp. 221-250, 24 Figs, July, 1957. See also two earlier papers by the same author :

1) Effects of Ground on Shaking in Earthquakes, *Trans. Amer. Geophys. Union,* Vol. 37, pp. 757-760, 1956.

2) Comparison of Seismograms Recorded on Mount Wilson and at the Seismological Laboratory, Pasadena, *Ann. de Géophysique,* Vol. 12, pp. 202-208, 1956.

Dr. Romney : Were the microseisms larger in the alluvial stations ?

Prof. Gutenberg : The short-period microseisms were much larger and sometimes made it impossible to record near the coast or near pumping oilwells. Carder reported several years ago that the alluvium in the Long Beach area is made unsteady by oilfield pumping.

Dr. Carder : The period of this disturbance is somewhat less than 1 sec. Are 3 to 6 sec microseisms recorded with higher amplitudes on alluvium than on rocks ?

Prof. Gutenberg : Yes, to some extent — especially near the coast. On our regular stations we have a great variation of microseism activity ; there is a ground factor of up to 10.

65.— *Prof. Richter* presents his paper on The Form of Isoseismals.

The increase of seismic intensity on unconsolidated ground is well known. This causes isoseismal curves to be affected by the presence of alluvial valleys or of mountain ranges. Variations in local ground, however, are not sufficient to explain certain differences in intensity (and irregularities of isoseismals) connected with differences in path between earthquake source and point of observation. The author believes that many such phenomena are due to differences in conduction and absorption of seismic waves along paths of different geological character. In California, the peculiar form of isoseismals for earthquakes originating on the east slope of the Sierra Nevada may be accounted for by relatively small attenuation of the waves in passing through those mountains. An example of conduction of seismic waves through rock, is the isolated area of high intensity at Monghyr in the Indian earthquake of 1934. Isoseismals in California and New Zealand show strong elongation parallel to the geological trends; that this is not merely due to extent of faulting is shown by its appearance in the California earthquake of 1952, where faulting occurred with trend transverse to the structures. The appearance of so-called « earthquake shadows » is probably a phenomenon of conduction.

This paper will be published in the *Bulletin of the Seismological Society of America.*

Dr. Keilis-Borok : What was the focal depth of the Indian earthquake ?

Prof. Richter : The focal depth was normal.

Dr. Båth : Intensity observations in Fennoscandia seem at first sight to lead to contradictory results in different cases. The paper of Gutenberg together with that of Richter may explain many of the observed features.

66. — The paper by *N. Pinar,* Relations entre l'activité sismique et les grandes structures tectoniques de la Terre, is only read in title.

La plupart des zones séismiques importantes sont englobées dans les zones orogéniques alpines. Ces régions sont aussi considérablement plus actives par rapport au reste des zones séismiques. De 32 zones séismiques importantes établies dans le monde, 22 sont situées dans le géosynclinal alpin ; 4 dans des secteurs faisant probablement partie de ce géosynclinal ; 5 seulement (St. Laurent, New Madrid, Charleston, Lisbon et Baykal) se trouvent dans le géosynclinal hercynien ou calédonien et deux régions séismiques importantes sont situées sur des boucliers anciens (Syrie — Rift Valley de l'Afrique Orientale et Hawai).

Selon certains auteurs (p. ex. Kober), le paroxysme alpin aurait produit des déformations assez étendues aussi dans le domaine des plis hercyniens - calédoniens et sur les boucliers anciens (formation de failles et grabens, élévation ou affaissement de blocs ou déformation des structures déjà existantes, plissement léger). Des tensions et des forces déjà existantes dans les aires extra-alpines ont dû être renforcées et des nouvelles forces créées dans les aires sous l'effet du paroxysme alpin.

La répartition des séismes à travers le monde est étroitement liée à la grande tectonique du globe terrestre. Les forces ayant produit les paroxysmes orogéniques sont évidemment aussi la cause du mouvement séismique. La raison et la cause des séismes est identique avec les phénomènes géophysicaux ayant causé la division de la croûte terrestre en boucliers consolidés « anciens » et zones élastiques géosynclinales et orogéniques.

Dans l'intérieur de ces zones, la répartition des épicentres dépend de facteurs tectoniques locaux : ils jalonnent les lignes épirogéniques là, où le mouvement épirogénique est bien développé ; ils accompagnent les structures orogéniques dans les secteurs, où le mouvement épirogénique est peu prononcé. Les lignes épirogéniques suivent grosso modo les axes des structures orogéniques ; les forces ayant créé ces deux types de mouvements tectoniques doivent donc avoir la même source.

The complete paper has been submitted for publication in *Publications du Bureau Central International de Séismologie, Série A, Travaux Scientifiques, Fasc. N° 20.*

67.— *Dr. Satô* reads the paper by *K. Wadati* and *T. Hirono:* On the Abnormal Distribution of Seismic Intensity.

In 1917, Mr. K Hasegawa reported a curious phenomenon that an earthquake originating off the coast of Japan Sea was felt by human bodies only on the Pacific coast of Japan but not in the coastal area of the Japan Sea. Afterwards one of the authors of the present report pointed out that this earthquake had its focus in a deep place and the deep-focus earthquakes occurring around Japan always revealed such an abnormal distribution of seismic intensity. We refer to this irregular distribution as « abnormal distribution of seismic intensity ». In general, the irregularity has been observed more remarkably as the focal depth increases. In other words, a deep earthquake and some shallow ones originating in a specific area are observed to give a special pattern of abnormal intensity distribution, having no definite connection with the geological condition of respective seismological stations. Thus, this phenomenon is considered to be interesting not only by itself but also very useful for the study of regional structure of the earth's crust.

Some noteworthy features in this phenomenon are as follows :

(1) In these areas, where a strong seismic intensity is observed non-instrumentally, the vibrations of short period are generally found to be more predominant in the seismogram comparing with the case of other areas.

(2) In these areas, arrival time of seismic waves is a little earlier than that expected by the standard travel time table.

(3) These areas have a general tendency to correspond to the positive anomaly area of gravity.

(4) These areas of distinct abnormal intensity seem to coincide with the areas of thinner earth's crust (Pg and P* layer).

(5) It is known that the seismic wave is propagated faster in the eastern part of Japan than in the western part, and this phenomenon is considered to have some connections with the abnormal distribution of seismic intensity.

The main object of this report is to show some typical examples of abnormal distribution of seismic intensity in Japan, and some discussions are made about the items mentioned above.

68. — *Prof. Beloussov* reads the abstract of the paper by *S. V. Medvedev* and *B. A. Petrushevsky :* Methods and Experience in Dividing the USSR Territory According to Seismic Intensity.

In seismically active regions of the USSR law-governed measures are taken to construct more earthquake-proof buildings.

To determine the value of seismic effects upon buildings, a special map of seismic intensity for the whole territory of the USSR is applied. In 1956 this map was revised and improved. The map of seismic intensity shows regions differing in earthquake intensity expected on the surface. The earthquake force is determined in intensity grades. A new seismic scale with twelve intensities, parallel in its description to the scale of Mercalli - Cancani - Sieberg, Wood - Neumann and to the new Chinese scale, has been worked out by Dr. S. V. Medvedev and published in 1953.

The map of seismic intensity of the USSR territory has been compiled on the basis of studying former earthquakes, geological and geophysical conditions of their occurrence and their peculiarities on the Earth's surface.

The results of earthquake registration at seismic stations during 40 years have been presented as an « Atlas of the USSR Seismicity », where earthquakes are divided according to their magnitude in the focus (M), and epicentres are divided in the accuracy of determining their co-ordinates and in focal depth.

Investigations of geological conditions of earthquake occurrence aimed at elucidating a relation between the geological structure of a region and its seismicity, special attention being devoted to revealing large structural complexes of their joints called seismic seam joints. A tectonical analysis makes it possible to find the extent of a relative mobility of the structural complexes. Earthquakes mainly occur in zones where modern tectonic movements are most active. Intensive relative vertical displacements of geological structures cause large shear stresses in the Earth's crust and lead to a formation of new faults or of displacements along already existing faults, thereby causing earthquakes.

To study present seismic activity, special expeditions including temporary seismic stations with high-sensitive equipment were organised. Within a short period of time these stations registered a great number of very weak earthquakes.

Investigations of engineering seismology are conducted to get a qualitative description of seismic motions on the Earth's surface and to determine intensities of probable earthquakes. Instrumental records served as a basis for determining average values of spectra of seismic motions. To get a better knowledge of seismic intensity, the influence of ground types and conditions of their occurrence upon earthquake intensity has been studied.

The map of the USSR seismic intensity has been compiled with the scale 1 : 5 000 000. Detailed seismic maps are compiled for some big cities.

The complete text will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Prof. Richter : Statistics of small earthquakes may not be the same as for large earthquakes.

Prof. Beloussov : We realize this too. We have many small earthquakes in the areas, where large earthquakes occur and we think there must be some relationship. We seek some solution to be used for the forecasting of large earthquakes. We are not sure it will work everywhere.

Prof. Richter : Neither are we.

The session is closed.

ELEVENTH SESSION

TUESDAY, SEPTEMBER 10 (morning)

Program

9. — Scientific communications : Geochronology and Radioactivity (cont.).

   69. — *H. Faul* and *G.R. Tilton :* Age of Some « Hercynian » Granites in Europe.

   70. — *J.P. Rothé :* Présentation d'une carte de la radioactivité des Vosges hercyniennes.

   71. — *M.V.N. Murthy :* Zircon Studies and Their Bearing on Dating Granites.

   72. — *A. Hée :* Détermination de l'âge absolu de deux granites de la chaîne des Vosges.

   73. — *R.E. Folinsbee* and *W.D. Ritchie :* Late Cretaceous Geochronology.

   74. — *P.W. Gast, O. Kouvo,* and *L. Long :* Absolute Ages from the Fennoscandian Shield.

This session, held jointly with the Association of Volcanology, is a continuation of the symposium organized by *Prof. Russell* (Ninth session). The session is opened at 09.00 a.m. with Prof. Russell in the chair.

9. Scientific communications : Geochronology and Radioactivity

69. — *H. Faul* and *G. R. Tilton :* Age of Some « Hercynian » Granites in Europe.

We have measured the age of several granitic rocks in the « Hercynian Chain » from the Oslo region, the Schwarzwald, the Vosges, the Alps, and the Massif Central. We have determined the uranium/lead, thorium/lead and lead/lead ratios on pure separated zircon, and the potassium/argon and rubidium/strontium ratios on clean separated biotite. The zircon results for all samples analyzed thus far are internally discordant and indicate that these zircons have been disturbed since their crystallization, so that the age of these rocks cannot be satisfactorily determined by the study of zircon alone. Rubidium/strontium and potassium/argon ages of the analyzed biotites agree and are all roughly the same, about 345±5 million years. The stratigraphic age of these rocks is certainly pre-Westphalian (pre-middle Carboniferous) and they are usually assigned to the Dinantian (lower Carboniferous). However, if we accept the Holmes time scale, our measurements would show the rocks to be Middle Silurian. It follows that either the time scale is not correct here, or the stratigraphic assignment must be in error.

The full text of the paper will be ready for publication at a later date.

70.— J. P. Rothé : Présentation d'une carte de la radioactivité des Vosges hercyniennes.

Le Professeur Rothé présente une *Carte de la radioactivité des Vosges hercyniennes.* Pour tracer cette carte établie à 1 : 100.000, on a utilisé plus de 4000 mesures effectuées sur le terrain avec différents appareils (chambre d'ionisation, gammamètres, gammaphones, scientillomètre). Le Professeur Rothé expose la technique des mesures, le détail des opérations sur le terrain, indique comment sont effectués les étalonnages et les corrections. Toutes les mesures ont finalement été exprimées en ions/cm^3/s et des isorades ont été tracées de 4 en 4 ions. Le travail a été exécuté en collaboration avec le Commissariat français à l'Energie atomique.

Les commentaires résumés qui ont été présentés et qui pourraient être beaucoup plus développés dans le détail montrent qu'une telle carte permet d'établir de nombreuses corrélations géologiques et dégage de façon particulièrement nette quelques-uns des traits fondamentaux de la structure des Vosges.

Le texte complet de la communication ci-dessus a été publié dans *Verhandelingen van het Koninklijk Nederlandsch geologisch-minjbouwkunding Genootschap, Geologische Serie,* Deel XVIII, Gedenkboek F.A. Vening-Meinesz, S'Gravenhage 1957, pp. 253-270, 9 fig., 2 pl. hors-texte.

A une question posée par un auditeur, le *Professeur Rothé* répond que les mesures ont toujours été faites sur des affleurements plans, dégagés de terre végétale et ne présentant pas d'effet de relief.

Le *Professeur Roubault* souligne l'intérêt du beau travail présenté par le Professeur Rothé qui permet de se rendre compte de l'exacte répartition de la radioactivité dans un massif hercynien complexe.

Prof. Rothé fait remarquer que les trois granites étudiés par Monsieur Faul dans les Vosges appartiennent aux massifs qui sur la carte de radioactivité présentée précédemment ont une activité analogue. Mais il y a dans les Vosges beaucoup d'autres granites et il serait dangereux d'extrapoler à l'ensemble du massif Vosgien les quelques données très intéressantes fournies par Monsieur Faul.

71.— M.V.N. Murthy: Zircon Studies and Their Bearing on Dating Granites.

Preliminary work in the Mineralogy Division of the Geological Survey of Canada confirms some of the conclusions reached by Poldervaart and others regarding the value of statistical studies of elongation, rounding index etc. of zircon crystals in concentrates, in understanding the origin of granitic rocks. Magmatic granites containing euhedral zircons with low rounding index can be distinguished from metasomatic granites containing zircons with high rounding index. Age determinations on only magmatic zircons will date the granite. This must be confirmed by statistical studies of zircon concentrates. Metamict zircons are more easily altered than non-metamict zircons and may lose U, Th and Pb. Comparison of ages of biotites and magmatic, non-metamict zircons, from Precambrian granites should prove useful in evaluating the reliability of zircons in dating.

72.— A. Hée : Détermination de l'âge absolu de deux granites de la chaîne des Vosges.

L'âge absolu des granites de Natzwiller et d'Andlau, appartenant à la chaîne des Vosges, a été déterminé par la méthode de E. Larsen, J. Keevil et H. Harrison.

Les zircons ont été retirés d'arènes prélevées en des points choisis, dans chaque massif, de façon à ne pas avoir à craindre la présence d'éléments provenant de roches étrangères.

L'extraction des zircons des arènes est une opération difficile pour obtenir des cristaux purs et en particulier celle des zircons d'Andlau a nécessité de nombreuses manipulations et un tri minutieux.

La radioactivité α a été mesurée en couches minces et en couches épaisses à la chambre d'ionisation et par la méthode photographique.

Le dosage du Pb a été fait par analyse spectrale quantitative à l'aide d'un spectrographe à réseau 2 M. A.R.L.

La chaîne des Vosges est hercynienne. Les âges trouvés sont respectivement :

Granite de Natzwiller $(300 \pm 20)\ 10^6$ ans

Granite d'Andlau $(225 \pm 25)\ 10^6$ ans.

The complete text has appeared in *Annales de Géophysique,* Vol. 13, No. 2, pp. 135-152, 2 Figs, 1957.

73.— R.E. Folinsbee and *W.D. Ritchie :* Late Cretaceous Geochronology.

The Kneehills tuff member of the Edmonton formation, of upper Cretaceous (Lance) age, is believed to have been derived from a late effusive phase of the Boulder batholith at Butte, Montana. The quartz monzonite of the Boulder batholith is 70 million years old (lead-alpha and potassium-argon ages are concurrent). Potassium-argon data suggest an age of more than 52 million years for the Kneehills tuff. The rhyolite at Butte is pipe or vent material from a volcano that is believed to be the source of the wind-carried, water-lain Kneehills tuff ; the rhyolite is younger than the Boulder monzonite. The heavy accessory suites, particularly the zircons, of the Butte rhyolite and the Kneehills tuff are remarkably similar. Dates for other igneous intrusives and extrusives in the Cordillera are greater than 70 million years and lend support to this correlation of the Boulder batholith rhyolite and the Lance tuff beds of Alberta.

The complete text has appeared in a paper by R. E. Folinsbee, W. D. Ritchie, and G. F. Stansberry : The Crowsnest Volcanics and Cretaceous Geochronology, *Alberta Society of Petroleum Geologists Guide Book,* Seventh Annual Field Conference, Waterton, September, 1957, pp. 20-26, 2 Figs, 3 Plates.

74. — *P. W. Gast, O. Kouvo,* and *L. Long :* Absolute Ages from the Fennoscandian Shield.

A number of age determinations on pegmatitic minerals and micas and zircons separated from granitic rocks are reported. Radioactive ages were measured using the decay of K^{40} to A^{40}, Rb^{87} to Sr^{87}, U^{238} to Pb^{206} and U^{235} to Pb^{207}. An apparent age of 1800 m. y. was found for four synkinematic and late kinematic Svecofennidic rocks. A similar age of 1800 m. y. was found for both a late kinematic and post kinematic kareledic intrusion. Muscovite associated with the Outokumpu ore body also gave an apparent age of 1800 m. y. Three postkinematic Svecofennidic granites and a Rapakivi granite were found to be 1620 m. y. old. These ages are compared to measurements made on potash rich schists and volcanics.

These and other absolute age determinations require considerable re-examination of the Precambrian geology as derived from field studies.

The session is closed.

TWELFTH SESSION

TUESDAY, SEPTEMBER 10 (morning)

Program

9.— Scientific communications : Constitution of the Earth.

75. — *C. Lomnitz :* Linear Dissipation in Seismic Body Waves.

76. — *H. Jeffreys* and *R. O. Vicente :* The Theory of Nutation and the Variation of Latitude.

77. — *E. P. Fyodorov :* Researches on Nutation in Connection with Some Problems of the Earth's Constitution.

78. — *N. Jobert :* Evaluation des plus grandes périodes propres de la Terre.

79. — *J. A. Mescherikov :* Modern State and Further Investigation of the Earth's Crust Secular Movement.

80. — *D. W. Allan :* The Moon as a Clue to the Earth's Early History.

81.— *E. V. Karus :* Absorption of Elastic Waves in Rocks.

82.— *M. P. Volarovich, Z. I. Stakhovskaya,* and *D. B. Balashov :* Investigation of Elastic Properties of Rocks at High Pressures in Connection with Geophysical Problems.

83.— *M. P. Volarovich* and *E. I. Parkhomenko :* Piezoelectrical Effect of Rocks.

84.— *Y. V. Riznichenko :* On the Application of the Ultrasonic Pulse Method to Seismological Problems.

85.— *O. Y. Schmidt* and *B. Y. Levin :* Origin and Composition of the Earth.

86.— *B. I. Davydov :* Physical Properties of Solid Bodies at High Pressures.

The session is opened at 09.00 a.m. with *Prof. Dix* as chairman.

9. Scientific communications : Constitution of the Earth

75.— *Dr. Lomnitz* presents his paper on Linear Dissipation in Seismic Body Waves.

Present data on creep of rocks, viscosity and creep recovery in the earth, attenuation, selective damping and dispersion of seismic waves, are reviewed. The data agree with a linear theory of dissipation which correlates the properties of creep, internal friction and dispersion for small strains. On the basis of the theory, expected values for dispersion, internal friction and viscosity in the interior of the earth are derived and discussed.

Reference is made to the following papers by the same author :

1) Creep Measurements in Igneous Rocks, *The Journal of Geology,* Vol. 64, No. 5, pp. 473-479, 5 Figs, 1956.

2) Linear Dissipation in Solids, *Journal of Applied Physics,* Vol. 28, No. 2, pp. 201-205, 3 Figs, 1957.

Sir Edward Bullard : Were those experiments done at ordinary temperature and pressure ?

Dr. Lomnitz : Yes. There are too few experimental data to tell the influence of temperature, and we do not know whether the effect of pressure might not balance the temperature effect. — In reply to further questions by Sir Edward Bullard, Dr. Lomnitz says the process is reversible and that the strain never exceeds 10^{-4}.

Prof. Benioff : You reach fracture conditions at that strain.

Prof. Press : Do you interpret your results to indicate that the same physical process is involved in the absorption of elastic waves and in the creep of rocks ?

Dr. Lomnitz : I did not go into the physical process, but I suppose that is the implication.

Dr. Das : Is there any plastic flow at high pressure ?

Dr. Lomnitz : Plasticity is not comprised in this theory. There is no stress threshold and the creep rate is proportional to the stress down to the smallest stresses.

Prof. Benioff : In experiment you get plasticity before fracture.

Sir Harold Jeffreys : Have you tried the effect of this kind of creep on the support of a mountain ?

Dr. Lomnitz : As the stress goes down so does the creep rate, and it is possible that times of geological magnitude will be required to produce appreciable deformation under these conditions.

Prof. Benioff : Did you use any other rocks ?

Dr. Lomnitz : Granodiorite and gabbro from San Diego County, Southern California.

Dr. Danes : Has any anisotropy been noticed ?

Dr. Lomnitz : The tests were in torsion along one direction only; however, the rocks would be expected to be anisotropic.

76. — *Sir Harold Jeffreys* presents the paper by *H. Jeffreys* and *R. O. Vicente* on The Theory of Nutation and the Variation of Latitude.

In most discussions of these phenomena it is supposed that the Earth is rigid. It is well known that a period of 305 days is derived for the variation of latitude; however, the actual period is nearly 430 days. Further, the amplitude of the 19-years nutation should be 9.227" whilst observations give about 9.207". Elasticity of the mantle lengthens the period of free vibration while fluidity of the core shortens it. We make use of Takeuchi's theory for the mantle and of two models for the core ; both models agree in mass and in moment of inertia with Bullard's theory of the figure of the Earth. One is homogeneous with a massive particle at the centre ; in the other the density is a quadratic function of the radius. The results for the actual Earth should be mid-way between these solutions and thus the astronomical data provide a check on the applicability of geophysical results.

Without the sea the free period should be around 395 days, but the effect of the sea lengthens it to 430 days. The 19-year nutation is likewise in good agreement except that theory predicts effects differing somewhat in obliquity and in longitude, which as yet have not been verified. The numbers h, k, l, which express the tides in the solid have been calculated. Their values differ according to the period.

Te complete text has appeared in the following two papers by H. Jeffreys and R. O. Vicente :

1) The Theory of Nutation and the Variation of Latitude, *Mon. Not. Roy. Astr. Soc.*, Vol. 117, No. 2, pp. 142-161, 1957.

2) The Theory of Nutation and the Variation of Latitude : the Roche Model Core, *Mon. Not. Roy. Astr. Soc.*, Vol. 117, No. 2, pp. 162-173, 1957.

Sir Harold Jeffreys, in reply to a question concerning Takeuchi's values for $\sigma = 0$, says that as far as he can remember his values lie between those for the two models studied here.

Dr. Danes : The period of the variation of latitude is 10^6 to 10^7 times longer than the periods of seismic waves. Are we justified to expect that the elastic parameters will be the same in both cases ?

Sir Harold Jeffreys : We find that both results check each other.

Sir Edward Bullard : Can you get the natural periods of the earth from these calculations ?

Sir Harold Jeffreys : No, because the statical theory is used for the shell. For free elastic motions the inertial and potential terms are comparable.

Sir Edward Bullard : You suggested that only half the density variation in the core might be due to compressibility. Do you think that there is really any reason to suppose that the outer core is not homogeneous ? If it were not, it would be very awkward for the theory of the earth's magnetic field, which seems to require motions in the core having a radial component.

Sir Harold Jeffreys : The Roche model would make the velocity of P in the core about 6 km/sec and hence makes it too compressible. The core, except for the central particle, is supposed to be of the same material in both cases. The mass of the central particle is about 4 % of that of the core, and is meant to give an idea of the effect of the inner core.

77.— The paper by *E. P. Fyodorov,* Researches on Nutation in Connection with Some Problems of the Earth's Constitution, is read only in title.

1. In the classical theory of nutation the Earth is assumed to be an absolutely rigid body. It was shown that the Earth's elasticity would produce the lengthening of the period of a free nutation and a reduction of the coefficients of the so-called Oppolzer's terms in forced latitude variations. Those are the only effects of elastic deformation on the Earth's rotation.

2. Fluidity of the Earth's core has been suggested to be capable of producing : a reduction of the constant of the nutation, a change of the form of the nutational ellipse, a lag in the nutation, an augmentation of the coefficients of the Oppolzer's terms, a lag in the forced latitude variations.

The object of this investigation is to examine if these effects are revealed by observations.

3. For this purpose we have availed ourselves of the most extensive and homogeneous series of latitude observations. The results obtained from 135 000 observations at Carloforte, Mizusawa and Ukiah from 1900 to 1934 are as follows :

A) The constant of the nutation is 9",198±0",002, while the theoretical value is near to 9",230. Taking into consideration the amount of the observational data used in our computation and the mean error of the result, it may be concluded that the usually adopted value 9",210 needs some negative correction, and that a discrepancy between the theoretical and observed values is even greater than it was hitherto considered.

B) The ratio of the axes of the nutational ellipse needs no correction.

C) The lag was found in the nutation in longitude only ; it is 3',8±1',2.

4. A total of about 230 000 observations at Pulkovo, Washington, Carloforte, Mizusawa and Ukiah was used to obtain the lunar diurnal term in the forced latitude variations. Its expression as derived from these data is :

$$\Delta\varphi = - \underset{\pm 1}{0''.009} \sin (S - 2☾ + \underset{\pm 4}{15^o}) + \underset{\pm 1}{0''.002} \sin (S + 2☾).$$

The theoretical expression as derived, taking into account the elastic deformation of the Earth, is :

$$\Delta\varphi = - 0''.005 \sin (S - 2☾),$$

where S is the local siderial time and ☾ the mean longitude of the Moon.

The complete text of this paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Sir Harold Jeffreys comments on this paper on the request by the chairman, Dr. Dix, and says : In the statement handed out by the Soviet delegates (see above) he says that he now finds the proportional effect to be the same in obliquity and longitude. Theoretically it seems necessary that that in longitude should be the greater. I hope that his work will soon be published.

78. — Mme Jobert presents her paper on Evaluation des plus grandes périodes propres de la Terre.

On applique le principe de Rayleigh au calcul de la période des vibrations propres de divers modèles de sphères élastiques ayant les dimensions de la Terre, pour des modes où l'indice des harmoniques sphériques est égal à deux. Dans chaque cas on s'efforce de faire la comparaison avec un calcul exact et d'utiliser une meilleure solution d'essai si l'erreur est trop grande.

On trouve :

— pour la période des oscillations de rotation (torsion) de la Terre, T = 44 minutes,

— pour la période des oscillations sphéroïdales, compte non tenu de la gravitation : T = 66 minutes,

en utilisant dans les deux cas, les données de K. E. Bullen.

L'effet de la gravitation a été évalué pour les oscillations sphéroïdales d'une sphère à manteau élastique homogène et à noyau liquide homogène, ayant respectivement les propriétés physiques moyennes du manteau et du noyau terrestre. La période est réduite de 7,1 minutes à une valeur comprise entre : 54,3 et 60 minutes.

The complete text has appeared in the following three papers by N. Jobert :

Evaluation de la période d'oscillation d'une sphère élastique hétérogène, par application du principe de Rayleigh (vibrations propres de rotation), *C. R. Acad. Sciences,* Paris, Vol. 243, pp. 1230-1232, 1956.
Sur la période propre des oscillations sphéroïdales de la Terre, *C. R. Acad. Sciences,* Paris, Vol. 244, pp. 921-922, 1957.

Sur la période propre des oscillations sphéroïdales de la Terre, *C. R. Acad. Sciences,* Paris, Vol. 245, pp. 1941-1943, 1957.

Prof. Pekeris : In your trial solution by the variational method, did you allow for the discontinuity in the horizontal displacement at the core boundary ?

Mme Jobert : Yes.

79.— Dr. Mescherikov presents his paper on Modern State and Further Investigation of the Earth's Crust Secular Movement.

Measurements of secular crustal movements have been made in the Western part of the European USSR, using three methods : A. Precise levelling ; B. Tide-gauge observations ; C. Geological-geomorphological research. Absolute values of crustal movement rate (mm/year) have been calculated for 250 points. Large zones of uplift separated by zones of absolute or relative subsidence have been found on the East-European plain. The zones have generally a meridional trend, one of the most remarkable uplift zones extending from the Baltic up to the foothills of the Carpathians. The average rates amount to 2—4 mm/year, with maximum uplifts up to 7—10 mm/year. It is concluded that secular movements are a most universal form of present tectonic manifestations, and that they cannot be fully explained by the theory of isostasy, as they exist also in extraglacial regions with undiminished intensity. The secular crustal movements are instead ascribed to endogenetic processes, apparently associated with displacements of subcrustal masses and possibly with changes in the volume of the planet. The crustal movements are of a complex oscillatory character and the sign of the movements can change in the course of geological time. The viewpoint of regarding platforms as absolutely aseismic areas is incorrect, and there is an obvious correlation between the epicenter locations and especially the flexure-like tracks separating sections of present uplifts and subsidences. The practical and theoretical importance of studies of secular crustal movements is emphasized and more extensive researches suggested.

A paper by J. A. Mescherikov entitled Secular Crustal Movements of the East-European Plain and Associated Problems will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.* The summary above has been made up from this paper.

Dr. Mescherikov says, in reply to questions by *Prof. Hess, Prof. Press,* and *Dr. De Bremaecker:* The cause of the movements is not known. — There is a correlation between secular motion and gravity anomalies, as outlined in the paper. — A profile of Bouguer gravity anomalies is under preparation.

Prof. Fairbridge : I wish to congratulate Dr. Mescherikov on his valuable contribution. One notes the correlation between basins and subsidence, and between domes and uplift. On a smaller scale in the Danube valley, Pavai Vajna (Ueber die jüngsten tektonischen Bewegungen der Erdrinde, *Földtani Közlöny,* Budapest, Vol. 55, pp. 282-297, 1926) showed contemporary uplift on anticlines and subsidence on synclines crossed by the river. On his world map, Dr. Mescherikov shows subsidence coinciding with all major coastal geosynclines. This suggests that his rapid oscillatory movement must be superimposed on a long-range tendency. Recent correlation by the speaker of the Carbon-14 dates from the Mississippi delta with those from more stable regions permits the removal of the post-glacial eustatic factor (about 30 m) for the last 10,000 years, leaving a residue of nearly 100 m for tectonic subsidence plus compaction ; this means a subsidence rate of 10 mm per year. The problem of the compaction is difficult to resolve. However, Dr. Mescherikov's evidence of rapid uplift in the extra-glacial areas of European USSR permits us to observe the secular movement devoid of the compaction problem.

Dr. Danes : If the basin areas are sinking, the movement would have to be comparatively recent, as the basins had to rise in earlier geologic times, otherwise, they would still be below sea level. Could some secular change in the gravity field introduce errors in levelling, so that the sinking would be fictitious ?

Dr. Mescherikov : The precise levelling is in progress. The Moscow basin is of Triassic age and older. We have to assume that between the Triassic and now, the basin raised and is now sinking back. — We are only beginning the geological interpretation of the results.

80. — *Dr. Allan* reads his paper on The Moon as a Clue to the Earth's Early History.

La Terre et la Lune ont probablement eu une origine commune de sorte que l'étude de l'évolution dynamique et tectonique de la Lune peut nous éclairer sur certains problèmes géophysiques et géologiques, surtout en ce qui a trait à la période primitive de l'histoire de la Terre. L'érosion n'agissant à peu près pas sur la Lune, le relief lunaire est peut-être très ancien et peut renseigner sur les phénomènes qui sont survenus sur la Terre à une période qui n'a laissé aucune trace géologique. De plus, l'éloignement progressif de la Lune et de la Terre dû au freinage exercé par les marées permet de fixer une limite quant à leur âge et quant au moment où les plaines lunaires, dites mers, ont pu être formées si on les considère comme des épanchements de lave. L'auteur examine les plus récentes théories formulées relativement à la surface lunaire et aux mers, en particulier, à la lumière d'une étude détaillée de l'évolution thermique de la Lune et montre que la formation de ces accidents, l'âge de la Terre et de la Lune et leur mode de formation ont entre eux d'intimes relations.

The paper will be published as follows :

1) *Journal of the Royal Astronomical Society of Canada,* a summary ;

2) The Thermal History of the Moon, *Mon. Not. Roy. Astr. Soc.*

Prof. Woollard : Does Dr. Allan have any explanation for the origin of the maria ? The research by Dr. Gerard Kuiper of Yerkes Observatory shows that the maria not only have a difference in surface texture (smooth vs rough) but also an elevation about 3 km below that of the surrounding rough areas. The survival of splash marks of obvious impact bodies in the maria are suggestive of only superficial amounts of dust in the maria and indicate molten conditions at the time of impact. Kuiper's idea that the maria represent local areas of radioactive melting with consequent reduction in volume of the original primary moon surface material, giving local areas up to 1000 km or more in diameter, seems a more reasonable explanation for the origin of these features, rather than a cataclysmic collision which could hardly be expected to produce the phenomenon observed. Even small impact craters such as Chub Crater in Canada show concentric waves peripherical to the crater boundary. No such features appear to exist on the moon except for the small craters in the maria which also have associated splash patterns.

Dr. Allan, replying to a question by *Dr. De Bremaecker,* says : Mare Imbrium is about 1000 km in diameter. Other maria range in diameter down to about 400 km.

Prof. Urey suggests re-showing slide of the Moon's surface, and says : The splash-marks leave little doubts that Mare Imbrium is an impact feature. As I understand Kuiper's views, he would *agree* with a cataclysmic origin for Mare Imbrium, though perhaps not for all. There has probably been some melting on the Moon, but many of the maria features can equally well be explained by dust or lava flows. As Kuiper points out, some of the regular patterns of ridges suggest an effect produced as lava cooled.

Dr. Benfield : The moon's surface has presumably remained static in its present form for a long time, whereas the earth's surface has been relatively-speaking churning around and perhaps still is. Do you believe this difference in behavior between the two bodies is due to recent (or present) heating in the earth's *mantle,* or rather due to the existence in the earth of a liquid *core* which the moon presumably lacks ?

Dr. Allan : The presence or absence of the core is not the important feature, I think, but as you say the thermal state of the mantle as compared to the completely cooled moon may be of importance.

81.— Dr. Riznichenko reads the paper by *E. V. Karus :* Absorption of Elastic Waves in Rocks.

1. One of the ways to perfect the methods of interpretation in seismology and seismic prospecting is to use the dynamical properties of the elastic wave propagation. To make a correct interpretation of the dynamic peculiarities, it is first necessary to know parameters characterizing the absorption properties of rocks. The study of these parameters may be of help in determining physical and mechanical properties of the rocks.

2. A decrease of the elastic wave energy during its propagation in rocks takes place mainly for three reasons : 1) an increase of the wave front surface (divergence) ; 2) dispersion of energy in non-homogeneous rocks ; 3) energy absorption due to a non-ideal elasticity.

There are many theories dealing with the absorption of elastic waves in solid media ; but there are none which would give a comprehensive explanation to the laws of seismic wave absorption in various rocks. The experimental studies of the absorption properties of rocks may be a decisive factor in forming such a theory.

3. To study the absorption properties of rocks, the so-called seismoacoustic method has been used. It was elaborated by the author in collaboration with I. P. Pasechnik on G. A. Gamburtzev's initiative and is based on the study of propagation of elastic harmonic motions in rocks with frequencies from 50 to 5000 cycles per sec.

Our methods of field observations with a proper treatment permit to determine a divergence index, decrement and absorption coefficient of stationary motions in rocks.

4. The results of the field determination of the parameters mentioned above make it possible to differentiate rocks in their absorption properties. The greatest absorption (value $\varkappa$) for each given frequency of oscillations was observed in sedimentary rocks occurring near the day surface (sandy loam, sand) ; the least absorption — for metamorphic rocks at a depth of 200—300 m (e. g. aegirine cherts).

The values of the absorption coefficients for some rocks increase with the frequency of vibrations under the law, similar to a linear one, i. e. the absorption coefficient is proportional to the frequency. The value of the absorption decrement for the same rock does not practically depend on the frequency.

The comparison of the values of the absorption decrement $\varkappa$ and phase velocities V_φ indicate that $\varkappa$ varies inversely to V_φ.

The experimental results of studying the absorption parameters for different rocks confirm, for the most part, some conclusions following from the theory of absorbing elastic waves due to an elastic after-effect (B. V. Deryagin).

Dr. Lomnitz : The constancy of internal friction in the range of 50-5000 c/sec from field data is an important addition to the few available data on that subject. Karus determined the logarithmic decrement, which differs only by a constant from the internal friction $1/Q$.

Prof. Press: Is the absorption coefficient constant or is the internal friction constant?

Dr. Riznichenko: The loss per wavelength is constant.

82. — *Dr. Riznichenko* reads the paper by *M. P. Volarovich, Z. I. Stakhovskaya,* and *D. B. Balashov:* Investigation of Elastic Properties of Rocks at High Pressures in Connection with Geophysical Problems.

Mechanical properties of rocks at high pressures are not sufficiently studied until now despite their undoubtedly considerable significance for geophysics and geology. Besides some data from the Handbook of Physical Constants for Geologists by F. Birch, J. F. Schairer and H. C. Spicer, only a few works have been published on this aspect (Birch, Griggs, Handin, Turner, Hughes and Jones, Robertson, etc.).

In the high-pressure laboratory of the Institute for Physics of the Earth of the USSR Academy of Sciences, methods of investigation of elastic properties of rocks at high all-sites pressures have been worked out. Samples of rocks sealed up in copper shells were placed into thick-wall steel bombs with a high gas pressure (N) up to 5000 kg per cm^2.

To measure velocities of elastic P waves in the rock samples filed in the form of bars 20—30 cm thick and with a 3 cm diameter, an impulse ultrasonic seismoscope with a cathode oscillograph was used. Electromechanical transformers made of dihydrophosphate of NH_4 (a radiator and a receiver of ultrasound) were placed inside the high-pressure bomb. Young's modula of rock samples were measured at high pressures by a statistical method of the plates bending for the first time. The plate of size $21\times1{,}5\times0{,}5$ cm cut out of a rock was placed horizontally on two supports inside the high-pressure bomb. A concentrated load in the plate centre was effected by a piston driven by a reductor. The measurement of the acting force and deformation (deflections of the plate) was carried out by elastic elements, dynamometer and deformator, with wire tensometric indicators of resistance pasted on them.

A rapid increase of P wave velocity (by 8—15 per cent) and of Young's modulus (by 30—80 per cent) of rocks (basalt, gabbro, sienite, dolomite, etc.) is observed if pressure rises up to 800—1200 kg per cm^2. If a further pressure rise goes on up to 5000 kg par cm^2 the velocity of elastic waves and Young's modulus increase but slightly. This is accounted for by a closing of pores in rock samples at pressures of the order of 1000 kg per cm^2. After that rocks acquire, to a great extent, properties of a solid, homogeneous elastic medium.

Pressures of 5000 kg per cm^2 correspond to depths of about 20 km in the Earth where the foci of destructive earthquakes occur. Therefore the obtained results can be used in the physics of earthquakes. They can be applied in the interpretation of data from seismic prospecting as well as in elaborating a theory of modelling geotectonic processes.

This paper will be published in full in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

83. — *Dr. Riznichenko* reads the paper by *M. P. Volarovich* and *E. I. Parkhomenko :* Piezoelectrical Effect of Rocks.

To elucidate the problem on the relation between electrical phenomena and seismic processes, laboratory investigations were made to reveal an electrification effect of rocks under the influence of mechanical stresses. The use of high-sensitive equipment (an ultrasonic seismoscope) permitted to find a new property of rocks, containing quartz grains, a piezoelectrical effect. The piezoeffect was found in granite, gneiss, quartzite, sandstone, etc.

The method consists in exciting elastic oscillations of ultrasonic frequency in a rock sample that in the case of a piezoelectrical effect transform into electric oscillations. Thereby, samples of the above rocks made in the form of rectangular parallelepipeds, worked as electromechanical transformers, i. e. as radiators or receivers of ultrasound.

In view of the discovered piezoelectrical effect in rocks, a theoretical investigation consisting of the determination of possible ideal piezoelectrical quartz textures (after A. V. Shubnikov) has been carried out. It was shown that when the texture consists of one (right or left) quartz modification and grains are orientated with respect to an electrical or optical axis, textures of symmetry ∞ or $\infty : 2$ may be respectively obtained. If there are two quartz forms in equal quantities, texture of symmetry $\infty . m$ is observed. The given symmetry is the most probable type for rocks so far as the rocks contain quartz of the right or left form in statistically equal proportions.

For an ideal texture $\infty . m$ wholly composed of quartz grains a piezoelectric modulus during a longitudinal effect must be equal to the quartz piezomodulus.

Quantitative measurements of piezoelectric modula by a statical method with a sensitive electrometer showed that the piezoelectrical effect in rock samples with a volume of dozens cm^3 is chiefly due to non-compensated quartz grains. It is approximately one hundred times less than in a monocrystalline quartz ; a size increase of the quartz grains in a rock makes its piezoelectrical modulus grow. The study of the longitudinal piezoelectrical effect on rock samples of different volumes (from 8 to 800 cm^3) showed that beginning from 300 cm^3 the size of a sample and the quartz size do not influence the piezoelectrical effect so far as in sufficiently large samples the effect is already observed due to the texture of the rock.

In samples of granites having a visible slaty cleavage the greatest piezomodulus was fixed on facets parallel to slaty cleavage, and the least or equal to zero in a direction normal to the sample linearity. The granite piezomodulus was found to be about 0.1 per cent of that of the monocrystalline quartz.

A small value of the piezoelectrical modulus in rocks is explained by the presence of a large amount of a piezoelectrical neutral component ; i. e. mineral grains revealing no piezoeffect as well as by an imperfect orientation of electrical axes of quartz grains in a rock.

A piezoelectrical effect of rocks is of interest for physics of earthquakes and may be important for new methods of electric prospecting to be worked out.

The complete text will appear in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

84. — *Dr. Riznichenko* presents his own paper On the Application of the Ultrasonic Pulse Method to Seismological Problems.

A short review is given of a series of investigations on the subject mentioned in the title of this article, made in the USSR during the last decade : a) modelling of seismic waves, b) determining the elastic properties of rocks in samples and in bore holes (ultrasonic well logging), and c) examining rock burst problems in connection with the problem of processes expectable in the tectonic earthquake foci.

The complete text has appeared in Russian in *Izvestia Akademii Nauk SSSR, Ser. Geofizicheskaya,* No. 11, pp. 1341-1346, Moscow, 1957.

The full paper will appear in English in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

See also Y. V. Riznichenko, B. N. Ivakin, and V. R. Bugrov : Modellversuche mit seismischen Wellen, *Bergakademie,* Freiberg, Vol. 2/3, 16 pp., 1954.

Y. V. Riznichenko and V. A. Gluchov : Ultrasonic Well Logging (in Russian), *Izv. Akad. Nauk SSSR, Ser. Geofiz.,* No. 11, pp. 1258-1268, 3 Figs, Moscow, 1956.

85. — *Mrs. Dr. Lubimova* presents the paper by *O. Y. Schmidt* and *B. Y. Levin :* Origin and Composition of the Earth.

1. All investigations of the chemical composition of the whole Earth (Chirvinsky, Clark, Link, Washington, Niggly, Zaslavsky, Fersman) are more or less explicity based on the conception of its origin, evolution and present internal structure. Besides, they widely utilize data on the chemical composition of meteorites which is not always founded by properly adjusted hypotheses on the origin of the Earth and meteorites.

2. Modern cosmogonic hypotheses by different authors consider that planets have formed from a cold gas-dust cloud. But considering an identical initial state of a planetary substance, these hypotheses differ much from each other in the very formation of planets.

3. Kuiper's conceptions on the formation of planets from massive gas-dust protoplanets lead to an originally incandescent state

of the Earth, the chemical composition of which was determined by a dissipation of the proto Earth's substance. However, as it was proved by Urey, the analysis of chemical evidences contradicts this point of view.

4. The analysis of astronomical and chemical data by O. Schmidt and his collaborators led to the development of a theory according to which the Earth was formed from a dusty component of the protoplanetary cloud by a gradual growth of an originally small embryo. After this theory, the Earth was originally cold and its chemical composition was conditioned by the condensation of various components present in the protoplanetary cloud.

5. By an analysis of chemical evidences, Urey has shown that the Earth's formation has begun with the accumulation of cold solid particles which accords with the conceptions developed in O. Schmidt's theory.

6. Meteorites are samples of a nonvolatile part of the protoplanetary cloud substance. The nonvolatile substances served to form the Earth (without hydrosphere and atmosphere) and other planets of the Earth's group. Therefore data on the composition of meteorites alongside with geophysical and geochemical ones serve as a basis for studying the chemical composition of the whole Earth.

The use of the data on the meteorite composition faces the following main difficulties :

1) our ideas on an average composition of the meteorite substance are distorted by a strong destruction and evaporation of meteor bodies during their flight through the atmosphere ;

2) as it was recently proved by A. A. Yavnel, meteorites now falling on the Earth's surface appear to be the disintegration product of five asteroids (or five asteroid groups) mainly differing in iron contents. Thus, even the true average composition of now falling meteorites can differ somewhat from the Earth's average composition.

Meteorites enable us to find the average composition of a stony and metallic part of the substance but cannot help in determining their relative portion in the Earth. In 1955 the metallic part in the Earth's composition was found to be $\frac{1}{7}$. According to the last hypothesis by K. E. Bullen a gravitational differentiation has taken place in the Earth's core which resulted in the formation of an inner core composed of nickel iron. In this case the metallic part in the Earth proves to be about 8 per cent. Based on K. E. Bullen's hypotheses and some new analyses of meteorites, a new table of the chemical composition of the whole Earth has been calculated. The comparison of the compositions of the Earth and its crust permits to reveal the elements which have been concentrated in the crust during the process of its formation and those which have remained in the mantle.

The complete text will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Facs. N° 20.* See also *Izv. Akad. Nauk SSSR, Ser. Geofiz.*, 11, pp. 1323-1331, 1957.

Prof. Urey : I disagree with Schmidt and Levin in regard to the composition of the Earth. I believe there is a variation of composition among the terrestrial planets and meteorites. The composition given by Schmidt and Levin for the Earth is about the same as that for the low iron group of chondritic meteorites as classified by Dr. Harmon Craig and myself. These contain about 22 % of total iron, of which 7 % is metallic. Another group of chondrites contain about 28 % of total iron, of which 15 % is metallic. The planet Mercury has a high density indicating the presence of about 65 % of metallic iron. These facts, quite independently of questions regarding the Earth and Venus in which high pressures obtain, indicate that a real variation in the proportions of silicate and metallic iron exists between the terrestrial planets, and that the Earth, Venus, and Mars most probably are intermediate in composition between Mercury and the Asteroids as is indicated by their densities. — I have had a most friendly correspondence with Dr. Levin and we both realize that the disagreement exists. Probably only additional data or theory will convince one or the other of us to change his mind.

86. — The paper by *B. I. Davydov,* Physical Properties of Solid Bodies at High Pressures, is presented.

1. Equations of state of solid bodies for the pressures important in geophysics cannot be obtained directly from experiments as the pressures far exceed those obtainable experimentally. This pressure region is still far from that in which the chemical composition of matter already loses its importance.

Approximate expressions for the free energy of typical crystalline bodies (ionic, valence, molecular crystals and metals) have been derived from the quantum theory of solid bodies. These expressions enable us to obtain, in the usual manner, the equation of state as well as compressibility and a thermal expansion coefficient as functions of pressure and temperature. The constants entering the formulae can be determined from the experimental data relating to low pressures. The resulting equations are valid up to the pressure at which some phase transition occurs.

Theoretical curves for several substances of interest for geophysics (NaCl, MgO, Fe_3O_4, Mg_2SiO_4, Si, Ge, Fe) well agree with the observational data in the pressure region attainable for the experiment.

2. The well-known experimental data indicate a considerable increase of electric conductivity of the Earth's mantle with depth. The ionic conductivity should decrease with the pressure growth. Therefore it may be thought that in the deep layers of the mantle electric conductivity is electronic.

The theory of electronic semi-conductors enables us to find the dependence of their electronic conductivity on the pressure and temperature. Analogous calculations are carried out for the coefficient of thermal conductivity too.

3. Theoretical calculations of phase transitions at high pressures, in particular the transition to the metallic phase, present

a more complex computation problem. Approximate methods of the quantum theory of the solid enable us to evaluate pressures at which such transitions occur. In Si the transition into the metallic phase should occur at a pressure of the order of magnitude up to 10^6—10^7 atm, whereas in MgO the transition takes place only at a pressure of the order of 10^8 atm.

The complete paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

The session is closed.

THIRTEENTH SESSION

TUESDAY, SEPTEMBER 10 (afternoon)

Program

9. — Scientific communications : Gravity Anomalies ; Isostasy.

87. — *W. A. Heiskanen :* Report on Isostasy.

88. — *W. A. Heiskanen :* Report on Geophysical Interpretation of Gravity Anomalies.

89. — *P. J. L. Melchior :* Rapport sur les marées terrestres.

This session, held jointly with the Association of Geodesy, is opened at 01.45 p.m. with *Prof. Tsuboi* as chairman.

The complete proceedings of this session are supposed to be published by the Association of Geodesy.

FOURTEENTH SESSION

WEDNESDAY, SEPTEMBER 11 (morning)

Program

9. — Scientific communications : Geochronology and Radioactivity (cont.).

90. — *U. Aswathanarayana :* Age of Pegmatites, India.

91. — *G. J. Wasserburg :* The Age of the Glenarm Series.

92. — *L. Cahen, P. Eberhardt, J. Geiss, F. G. Houtermans,* and *P. Signer :* On a Certain Correlation between the Isotopic Composition of the Lead of Galenas and their Content of Trace Elements.

93. — *R. D. Russell* and *R. M. Farquhar :* Isotopic Analyses of Leads from Broken Hill, Australia.

94. — *R. M. Farquhar* and *R. D. Russell :* Anomalous Leads from the Upper Great Lakes Region of Ontario.

95. — *A. P. Vinogradov :* Isotopic Composition of the Chemical Elements of Meteorites and the Crust of the Earth and Geochemical Conclusions.

96. — *S. F. Singer :* Cosmic Ray Evidence on the Origin of Meteorites.

This session, held jointly with the Association of Volcanology, is a continuation of the symposium organized by *Prof. Russell* (see Ninth and Eleventh Sessions). The session is opened at 09.00 a.m.

9. Scientific communications : Geochronology and Radioactivity (cont.)

90.— U. Aswathanarayana : Age of Pegmatites, India.
No summary or reference is available for this paper.

91.— G. J. Wasserburg : The Age of the Glenarm Series.

From A^{40}/K^{40} determinations on pegmatitic micas and micas produced during metamorphism in the Glenarm series it is concluded that both the age of metamorphism of the Glenarm series and the time of pegmatite injection was about 350 m.y., corresponding to the Ordovician period on the Holmes time scale. The absolute age is seen to coincide with the ages of pegmatites in New England and North Carolina. This evidence supports the view that the whole eastern Appalachian region was « simultaneously » subject to vigorous igneous and metamorphic activity about 350±20 m.y. ago.

The thesis that the Glenarm series is Precambrian because of its degree of metamorphism is untenable on the basis of the data presented here. These A^{40}/K^{40} dates do not, however, preclude the possibility that this series was originally deposited during Precambrian time.

The general agreement obtained on materials from such contrasting lithologies as the Cockeysville marble, the Setters Quartzite and the cross-cutting pegmatites indicates that it is sometimes possible to determine the ages of micas formed during profound metamorphic episodes. Such micas do not appear to show any effect of inheritence of argon.

Reference is made to a paper by G. J. Wasserburg, F. J. Pettijohn, and J. Lipson : A^{40}/K^{40} Ages of Micas and Feldspars from the Glenarm Series Near Baltimore, Maryland, *Science*, Vol. 126, pp. 355-357, 1957.

92.— L. Cahen, P. Eberhardt, J. Geiss, F. G. Houtermans, and *P. Signer:* On a Certain Correlation between the Isotopic Composition of the Lead of Galenas and their Content of Trace Elements.

That the isotopic composition of common lead varies in a significant way with the age of the lead occurrence is now well known. Providing certain assumptions are made, this isotopic composition can be used for an estimate of the age of the mineral. This « model » or « conventional » age is often quite satisfactory. However, there exist a certain number of leads which do not conform to the systemacy generally observed.

The purpose of this study is to investigate certain aspects of the geology and geochemistry of those leads, the model ages of which are older than the geological age. Their isotopic composition usually appears to be perfectly normal and if the age of the host formation or of the emplacement of the lead occurrence is unknown it may be impossible to detect which leads belong to this type, so that the search for criteria enabling to recognize them is of some importance.

20 leads from the Alps and 24 from North Africa have been studied. In each case the model age, derived from the isotopic composition has been compared to the age of the host formation or that of the emplacement of the galena. The silver content (and that of some trace elements) of each of these galenas has been measured and compared to the above mentioned ages.

Practically all the galenas we have investigated which have model ages comparable to the age of the host formation are found in veins, often with more or less obvious magmatic connexions and are silver rich.

On the other hand, the leads of these occurrences, located in sedimentary rocks, and apparently independent of igneous activity are poor in silver and have model ages which are older than the host formation.

The origin of the latter, « telethermal », type of occurrence has often been debated and it has been suggested that these occurrences are « rejuvenated » from an older source of ore. This seems to be borne out by the fact that it is precisely occurrences of this type which contain leads with model ages older than age of host formation.

It thus seems that when the age of the host formation is known, isotope analyses of lead minerals and the model age derived therefrom constitute objective criteria enabling to distinguish which occurrences are emplaced for the first time and which are derived or rejuvenated.

In formations of unknown age, a similar criterion which might furnish the same information appears to be the silver content of the galena as, in each of the areas, which have been studied, we have found that, as regards silver content, there is a sharp distinction, with little or no overlap, between leads with model ages in agreement with age of host formation and those with model age older than that of host formation.

93. — *R. D. Russell* and *R. M. Farquhar:* Isotopic Analyses of Leads from Broken Hill, Australia (with Spectrographic Analyses by *J. E. Hawley*).

This paper presents the results of isotopic analyses for twenty-four leads extracted from galenas from Broken Hill, New South Wales, Australia and analysed at the University of Toronto. Some of the galenas occurred in conformable ore deposits of the Broken Hill type and some occurred in weak, gently dipping fractures and are of the Thackaringa type. We interpret the isotopic analyses as indicating that the conformable ores are *ordinary* leads and the Thackaringa ores are *anomalous* leads, that the probable age of the ordinary leads is about 1500±150 million years, that the Thackaringa leads were derived from the conformable ores in a process that involved the addition of anomalous proportions of radiogenic lead from the country rocks, and that the addition of the anomalous radiogenic component occurred within a few hundred million years of the time of formation of the conformable ores.

Qualitative spectrographic analyses of some of the ores were carried out at Queen's University, Ontario, and are included in the paper. Most significant is the fact that the anomalous leads are distinguishable from the ordinary leads on the basis of trace element content. The significance of the spectrochemical analyses is discussed.

The complete paper has been published in *Trans. Amer. Geophys. Union,* Vol. 38, No. 4, pp. 557-565, 4 Figs, August, 1957.

94. — *R. M. Farquhar* and *R. D. Russell :* Anomalous Leads from the Upper Great Lakes Region of Ontario.

We have previously reported on the presence of lead minerals of anomalous isotopic composition in the Sudbury, Ontario, mining area, and have used these anomalous isotope ratios in trying to determine the history and age of the Sudbury ores. We have since found a number of anomalous leads in the upper Great Lakes region of Ontario, some of which are more anomalous than the most anomalous Sudbury galenas. As in the case of Sudbury, the anomalous leads vary enormously in isotopic composition, even when closely related geographically. Leads found in the Thunder Bay region show extreme variation. There seems to be a correlation between isotopic composition and distance from the Lake Superior shore. Those leads nearer the shore have generally large radiogenic components. Leads some distance northwest of the lake are not apparently anomalous, having the isotopic constitution typical of the old Keewatin leads. This paper attempts to explain some of the isotopic relationships noted for these leads and to compare and contrast them with the anomalous leads from Sudbury.

The complete paper has been published in *Trans. Amer. Geophys. Union,* Vol. 38, No. 4, pp. 552-556, 3 Figs, August, 1957.

95. — *A. P. Vinogradov :* Isotopic Composition of the Chemical Elements of Meteorites and the Crust of the Earth and Geochemical Conclusions.

No summary or reference is available for this paper.

96. — *S. F. Singer :* Cosmic Ray Evidence on the Origin of Meteorites.

The birth of a meteorite coincides with the breakup of its parent body and also with the beginning of the meteorite's exposure to cosmic rays. This continued exposure creates through nuclear evaporations definitely calculable amounts of He^3, about 2/3 of it by way of tritium. Hence the date of breakup can be obtained from the He^3 content ; or better still, from the He^3 and tritium content measured in the same sample. However, the latter method has only limited applicability. The two methods give good accord ; of six meteorites dated, all are found to be about 300 million years old. This agreement establishes confidence in the calculations of He^3 production and leads to some considerations concerning the process of nuclear excitation. The age is also in good accord with Öpik's calculation of the mean lifetime of meteorite-like bodies against capture by the inner planets. From this agreement conclusions can be drawn concerning the mechanism of meteorite creation and concerning the relative constancy of cosmic ray intensity as far back as 300 million years.

The paper has been published partially in the *Irish Astronomical Journal,* Vol. 4, No. 6, pp. 165-180, June, 1957. A paper embodying some of the latest results has been submitted to the *Physical Review.*

The session is closed.

FIFTEENTH SESSION

WEDNESDAY, SEPTEMBER 11 (morning)

Program

9. — Scientific communications : Seismic Waves.

97. — *R. A. Ross :* Waves Generated by a Submarine Earthquake.

98. — *J. N. Nanda :* Seismic Exploration of the Continental Shelf off the West Coast of India.

99. — *D. S. Carder, L. F. Bailey,* and *J. Hershberger :* Seismic Wave Travel Times from Surface Foci.

100. — *C. Lomnitz :* Internal Friction in the Earth's Crust from Aftershock Sequences.

101. — *J. Cl. De Bremaecker :* Transmission and Reflection of Rayleigh Waves at Corners.

102. — *J. B. Hersey :* Seismic Refraction Measurements at Sea East of the Southeastern Coast of the United States.

The session is opened at 09.00 a.m. with *Prof. Benioff* in the chair.

9. Scientific communications : Seismic Waves

97. — *Mr. Ross* presents his paper on Waves Generated by a Submarine Earthquake.

On a déterminé la solution du problème posé par une source linéaire (source d'ondes P et S à la fois) dans un milieu élastique semi-infini recouvert d'une couche de fluide incompressible soumise à l'action de la gravité. La solution exacte (valable pour les points très éloignés de la source) est obtenue par la méthode d'expansion et par l'intégration prise le long d'un contour. On s'est particulièrement occupé des ondes produites à la surface libre du fluide. Elles prennent deux formes : ondes de dispersion (gravité) analogues à celles qu'on étudie dans le problème Cauchy-Poisson, et ondes produites par l'onde Rayleigh à la surface qui sépare la matière solide du corps fluide.

Prof. Press : What is the physical significance of the C_1 and C_2 waves ?

Mr. Ross : They represent the influence on the water of the P and S waves travelling out from the source. They have the sharp cut-off and sharp onset characteristics of the Rayleigh wave.

Sir Harold Jeffreys : The assumption of an incompressible fluid seems doubtful. The velocity of Rayleigh waves is greater than that of longitudinal waves in water.

Mr. Ross : The reason for choosing an incompressible fluid rather than a compressible one, was simply that the problem of the compressible layer was found to be not solvable by this method (Cagniard's method).

Sir Harold Jeffreys : That is the disadvantage of Cagniard's method ; it is so hard to apply.

Dr. Knopoff : Your expression Δ should show the coupling between the liquid layer and the elastic solid beneath, i.e. the roots of $\Delta_1 = 0$ should yield the usual Stoneley wave velocities for two media in contact (see E. Strick and A. S. Ginzbarg : Stoneley-Wave Velocities for a Fluid-Solid Interface, *Bull. Seism. Soc. Amer.*, Vol. 46, No. 4, pp. 281-292, 20 Figs, October, 1956). This denominator should show roots corresponding to a water layer over the elastic half-space. — The onsets of the wave trains should show infinities in time corresponding to the delta function time dependence of the source.

Mr. Ross : The pole that arrives here is the zero of a more complicated expression than the usual one for a semi-infinite solid. It is actually the one that arrives by considering a semi-infinite liquid in contact with a semi-infinite solid.

Dr. Knopoff : Then it is a Stoneley pole.

Mr. Ross : Yes, if one lets certain parameters in the Stoneley case tend to zero or infinity, one obtains the result. — In reply to questions by *Dr. Field,* Mr. Ross says that he uses a classical elastic solid, i.e. a solid in which only small displacements are considered.

98. — The paper by *J. N. Nanda,* Seismic Exploration of the Continental Shelf off the West Coast of India, is read only in title.

Some recent observations in connection with seismic exploration of the continental shelf off the west coast of India are described. A single ship with a single sono-buoy was used. Five shots were fired at distances up to six miles from the sono-buoy. Roughly, the depth of the ocean was about 80 fathoms, and a negative temperature gradient existed. The exact times of shots were calculated from the observed arrival of direct waves. The loose sediments are surmised to be about 2.8 km thick, and seismic velocity in these sediments is found to be 1.2 miles per second. The depth of sediments has been calculated from assigning a broad maximum in the records to reflection from the bottom of the loose sediments.

The complete text of this paper has been published in the *Journal of Geophysical Research,* Vol. 62, No. 1, pp. 113-115, March, 1957.

99. — *Dr. Carder* presents the paper by *D. S. Carder, L. F: Bailey,* and *J. Hershberger:* Seismic Wave Travel Times from Surface Foci.

The results of an extensive study of travel times of seismic waves generated by nuclear explosions over the Nevada and Pacific Islands proving grounds are summarized. Data that can be used for direct comparison between the two dissimilar source areas are meager because the distances to which the Nevada sources have been recorded when referred to the Pacific sources does not extend beyond neighboring oceanic islands on which reliable seismographs are difficult to maintain. Nevertheless, there are comparisons which indicate regional differences, the chief of which are earlier times of arrival from the Pacific sources. In the distance zones where seismograph coverage is good, deviations from a norm because of station position or azimuth are apparent. This study affords an excellent check of timing accuracy at various stations, and points out the necessity of maintaining a reliable time standard which may include automatic recording of time signals several times a day. More important, it affords a check on existing or disputed ideas of mantle and crustal structure and suggests new ones.

Prof. Gutenberg: The data from the Nevada explosions fit well the « low-velocity layer model ». If the increase in temperature with depth is the main reason for decrease in velocity in the upper part of the mantle, this decrease should be smaller under deep oceans, where the temperature at the ocean bottom is much lower than it is at the same depth under continents.

Mr. Bailey says, in reply to a remark by *Dr. De Bremaecker,* that they prefer to use standard errors, and he agrees that this should be stated.

Prof. Press: It is interesting to me that Dr. Carder obtains velocities of 6.15 km/sec and 8.2 km/sec for the upper crust and mantle respectively. These velocities support the view that Rayleigh-wave phase-velocity variations are due to thickness changes. Using the phase-velocity method we obtain a crustal thickness of 40—45 km in the basin-range province (California). That Dr. Carder's depth results agree with phase-velocity determinations only if a 7.3 km/sec zone is included in the crust, is extremely significant.

Prof. Woollard: Gravity data would give 41 km in that area.

Prof. Dix: Is it correct that the Mt. Hamilton station shows no delay due to mountain roots, whereas Fresno does show delay? What happened to the effect of mountain roots at Mt. Hamilton?

Dr. Romney suggests up and down dip shooting to get an explanation.

Prof. Benioff: The phenomenon may be due to greater distance from roots to Mt. Hamilton.

100.— Dr. Lomnitz presents his paper on Internal Friction in the Earth's Crust from Aftershock Sequences.

Using published data by Benioff, aftershock sequences are analyzed on the assumption that they represent creep recovery of the strained epicentral region. The values of the creep constant thus obtained are mutually consistent, and tend to support an empirical relation between magnitude of the main earthquake and volume of the strained zone, as follows :

$$\log V = M + 12.5$$

The values for the creep constant obtained from aftershock sequences agree with laboratory values and with the calculated values for internal friction in the earth's crust.

Prof. Tsuboi : I would like to point out that there are two types of large earthquakes, A and B, so far as Japanese earthquakes are concerned. For A, the deformation of the earth's crust at the time of the main shock and that after the shock are of the same direction, while for B, they are of opposite directions.

Prof. Benioff : Dr. Lomnitz used only one type.

Sir Harold Jeffreys : In analysing the aftershocks of the Tango earthquake (1927) I found that the probability of an earthquake in an interval dt after the main shock was of the form dt/t. Comparison with Dr. Lomnitz's result would suggest that all aftershocks have the same energy. — There is a great variation in the number of aftershocks for a given earthquake. Notably there was one in November, 1938, which doubled the size of a number of the I.S.S. It would be interesting to know whether this is closely correlated with energy.

Dr. Tocher : In answer to Sir Harold's last question, there is no doubt that in a general way, the number of aftershocks increases with the size of the main shock. On the other hand, 3 shocks of magnitudes between 5 ¼ and 5 ½ have occurred in the San Francisco Bay region within the past 2 years, for which the aftershock patterns have been quite dissimilar. The San Francisco shock of March 22, 1957, was followed by an enormous number of aftershocks, while the shocks of September 4, 1955, and October 24, 1955, were followed by comparatively minor aftershock series.

Prof. Benioff : The Mexican earthquake of July 28, 1957, had very few aftershocks, whereas the Aleutian earthquake of March 9, 1957, had very many.

Dr. Båth : In cases of one main earthquake followed by a series of aftershocks, the following rule holds remarkably well between the magnitude of the main shock (M) and the magnitude of the largest aftershock (M_1) : $M - M_1 \cong 1.2$.

Prof. Richter : The most recent good instance of Båth's law $M - M_1 \cong 1.2$ is the Mexican earthquake of July 28, 1957. Several days elapsed between the main shock ($M = 7.5$) and the first large aftershock ($M_1 = 6.3$).

Dr. Carder : I wish to call attention to the Helena, Montana, earthquakes of 1935, in which the magnitude of an earthquake was about the same as the main shock two weeks earlier. Also these were relatively small shocks followed by several thousand aftershocks.

Prof. Richter : Such pairs of shocks as the Montana earthquakes of October 18 and 31, 1935, of nearly equal magnitude, belong to a different tectonic pattern than the normal aftershock sequences. This is evident from the occurrence of earlier shocks beginning on October 4 and increasing ; the entire event resembles an earthquake swarm, not characteristic of the type discussed by Dr. Båth.

101. — *Dr. De Bremaecker* presents his paper on Transmission and Reflection of Rayleigh Waves at Corners.

The methods of model seismology were used to investigate the phenomena occurring when a Rayleigh wave is incident upon a corner whose angle is comprised between 0° and 180°. The wave bends its path for angles between 130° and 180°. For smaller angles large and abrupt variations in reflection and transmission occur ; the wave travels to the extremity of the corner and never « cuts corners » ; only about 50 % of the energy of the incident surface wave is preserved as such, the rest goes into body waves ; for a 90° corner the proportion is about 23 % in P and 26 % in S, with sharply preferential angles of incidence.

The complete text will be published in *Geophysics,* April, 1958.

Prof. Pekeris : Classically an edge acts like a line source. Does it follow from your work that when the angle is less than 90° the corner effectively acts like a line source, but that when the wedge angle is greater than 130° there is no longer a line source effect ?

Dr. De Bremaecker : Yes.

Dr. Knopoff : The most striking feature of your transmission coefficients is the highly oscillatory character when considered as a function of the angle of the wedge. Cannot this be interpreted in terms of an interference between the virtual source at the corner and a transmitted Rayleigh wave coupled between the two surfaces ? If this is a correct interpretation, then cannot these oscillatory responses be characteristic of the frequency which you used ? A crucial test of this would be an observation of a phase shift in the wave form of the transmitted Rayleigh pulse as a function of the angle of the wedge.

Dr. De Bremaecker : We tried to check this ; it is probably not of crucial importance.

Dr. Stoneley : Could you give us an idea of the relative dimensions of the apparatus ? Is the motion two-dimensional or does the third dimension enter ?

Dr. De Bremaecker : The sheet was 2 mm thick and 60 cm wide, so that the motion is effectively two-dimensional.

Prof. Benioff : This is a function of the number of wave lengths only.

102.— Dr. Hersey reads the paper on Seismic Refraction Measurements at Sea East of the Southeastern Coast of the United States.

39 seismic refraction profiles, mostly reversed, have been established along the continental shelf (about 40 meters deep) on the Blake Plateau (about 800 meters deep), and in deep water (2500 to 4500 meters deep) east of the Carolinas, Georgia, and Florida and north of 29° N. Lat. Under the continental shelf, structures agree with those found on land and appear to be a simple seaward extension of them. Compressional wave velocities range from 1.6 to 6.1 km/s, with layers between 5.8 and 6.1 km/s having depths corresponding to the granitic basement on land.

Structures beneath the Blake Plateau were measured extensively only at shallow depth because most of the profiles were too short, owing to rough weather. A layer of 5.2 to 5.5 km/s lies about 3 km below sea level over the northern half of the Plateau. Several layers from 1.7 to 4.5 km/s are generally flat-lying at shoaler depths, but show evidence of faulting (probably normal) and other structural change. A few measurements of high velocities indicate a layer about 6.3 to 6.7 km/s at depths from 5 to 9.5 km, the latter depth being the more satisfactorily established. An 8.0 km/s layer at 14.5 km is inferred from a single, unreversed profile of high quality. Until a number of longer profiles are established on the Blake Plateau the interpretation of these higher velocity measurements remains in doubt.

In the deep water the normal ocean basin structure was observed at one location only. Other profiles were located in various relations to a deep topographic ridge extending out from the continent in line with the trend of the Cape Fear Arch in North Carolina. The structure appears to be rather more like deep ocean basin structures than continental but the sections contain several layers between 1.8 and about 8.4 km/sec. Highest velocities range from 7.5 to 8.4 km/s at depths from 13 to 17.5 km/s. One unreversed measurement indicates a layer depth of 21 km at 8 km/s. The structures are complicated, with evidence of faulting and considerable horizontal change over a few miles. The topographic ridge appears to be a structural feature as well, but its relationship to continental structures is not obvious from data in hand.

The details of the results of this work and the geological interpretation will be presented in a forthcoming paper by J. B. Hersey, Elizabeth T. Bunce, R. F. Wyrick and F. T. Dietz.

The session is closed at 12.00.

MEETING OF THE EUROPEAN SEISMOLOGICAL COMMISSION

WEDNESDAY, SEPTEMBER 11 (afternoon)

Mr. Peterschmitt, Secretary of the European Seismological Commission, has kindly given the following report of this meeting.

Les membres de la C.S.E., présents à Toronto et d'autres personnalités se sont réunis le 11 septembre 1957 afin de discuter quelques points d'organisation de la prochaine assemblée générale d'Utrecht.

Ont assisté à la réunion : MM. Båth, Caloi (Président), Demetrescu, Egyed, Keilis-Borok, Mme Labrouste, Mlle Lehmann, MM. Meisser, Morelli, Peterschmitt (Secrétaire), Rothé, Stoneley, Veldkamp.

La séance est ouverte à 14 h. 00 par le Président Caloi qui indique que le premier but de cette réunion est de fixer la date précise de l'Assemblée d'Utrecht.

D'après M. Veldkamp les seules possibilités d'accueil à Utrecht sont réalisées pendant les vacances scolaires, périodes pendant lesquelles on peut disposer des locaux de l'Université.

On a cherché à concilier notre réunion avec celle que doit tenir fin mai, début juin en Hollande l'European Association of Exploration Geophysicists (E.A.E.G.). Ceci n'a pas été possible. En fin de compte il est décidé que la prochaine réunion de la C.S.E. aurait lieu à l'*Université d'Utrecht* du 8 au 12 avril 1958.

En ce qui concerne le programme, il est décidé de poursuivre les études entreprises sous forme de symposia dirigés par des rapporteurs. Ce sont :

a) *Ecorce terrestre :* Rapporteur : Prof. Closs.

En particulier : résultats obtenus au moyen de grandes explosions (rapport de la sous-commission des explosions alpines). Organisation de nouvelles expériences.

b) *Appareils :* Rapporteur : Prof. Gassmann.

Rapport de la sous-commission de la plate-forme. Enregistrement par des appareils homogènes des séismes éloignés.

c) *Catalogue macroséismique,* Relations entre les données macroséismiques et la Magnitude, Carte séismique de l'Europe : Rapporteur : M. Båth.

d) *Interprétation dynamique des séismes :* Connections entre la séismicité et la tectonique : Rapporteur : M. Keilis-Borok.

a) *Ondes canalisées en Europe :* Rapporteur : M. Båth.

La séance est levée à 14 h. 45

SIXTEENTH SESSION

WEDNESDAY, SEPTEMBER 11 (afternoon)

Program

9. — Scientific communications : Geothermy and Tectonophysics.

A) Geothermy.

103. — *B. F. Grossling :* Temperature Changes in the Earth due to the Formation of a Geosyncline.

104. — *J. A. Jacobs* and *D. W. Allan :* Temperatures in the Primitive Earth.

105.— *L. Knopoff :* The Lateral Temperature Inhomogeneity in a Static Earth.

106.— *E. A. Lubimova :* The Earth's Thermal History and its Geophysical Consequences.

B) Tectonophysics.

107.— *V. V. Beloussov :* On Types and Origin of Folding.

108.— *V. V. Beloussov :* Development of Geosynclines.

109.— *M. V. Gzovsky :* Method of Modelling in Tectonophysics.

110.— *J. T. Wilson :* Evolution of the Crust and its Rock Associations.

111.— *L. Glangeaud :* Classification géodynamique des différents types de chaînes plissées et origine des déformations.

112.— *R. W. Fairbridge :* Statistics of Non-folded Basins.

113.— *M. Ewing, B. C. Heezen,* and *J. Hirschman :* Magnetic Anomalies and Seismicity in the Mid-Atlantic Ridge and its Extensions.

This session is held together with the Association of Volcanology. It is opened at 02.05 p.m. with *Sir Edward Bullard* as chairman during the first part (Geothermy) and continues at 04.20 p.m. with *Prof. Rittmann* as chairman during the second part (Tectonophysics).

9. Scientific communications: Geothermy and Tectonophysics
A) Geothermy

103.— *Dr. Grossling* reads his paper on Temperature Changes in the Earth due to the Formation of a Geosyncline.

The object of this paper is to study the changes in the temperature distribution in the earth's outer layers, resulting from subsidence and sedimentation occurring during the formation of a geosyncline.

The perturbation of the thermal equilibrium due to rapid subsidence is studied separately for the two cases : (a) when the heat comes from the deep interior and (b) when it is generated in the crust. The effect of the distortion of the plastic substratum has been taken into account. The limitations resulting from the assumption of an instantaneous subsidence are discussed. Temperature variations, down to depths of about 100 km and for time intervals up to 300×10^6 years, are calculated for subsidences of 6 and 13 km. Formulae and tables are presented for calculating the decay of various initial temperature distributions and for determining the build-up of the temperatures produced by slab distributions of heat sources.

Application of these results to the interpretation of observed geothermal gradients is discussed, and their bearings on lithification and upon the mechanical crustal strength is also considered. It is suggested that the decrease of crustal strength, resulting from increase of temperature during subsiding in the evolution of a geosyncline, may have a triggering effect in determining the time when folding begins.

The complete paper is submitted for publication in the *Transactions of the American Geophysical Union.*

Prof. Rittmann : The very interesting study of Dr. Grossling should be completed by considering also the chemical reactions and the recrystallizations which, in nature, influence strongly the distribution of temperatures in the geosynclinal sediments.

104.— Dr. Allan presents the paper by *J. A. Jacobs* and *D. W. Allan :* Temperatures in the Primitive Earth.

Les théories récemment formulées sur l'origine du système solaire ne précisent pas quelle devait être la température initiale des planètes. La seule façon d'étudier cette question en ce qui touche la Terre semble être la suivante : choisir une série d'hypothèses différentes sur l'état initial du globe et étudier dans quelle mesure l'évolution subséquente de la Terre concorde avec les données disponibles, par exemple le temps depuis lequel la Terre a pris à peu près sa forme actuelle, l'âge des roches de la croûte terrestre, l'état actuel de l'intérieur du globe, etc... Certaines des difficultés qui surgissent lorsqu'on veut adopter une température initiale précise sont étudiées pour ce qui est de deux cas précis : premièrement, si l'on suppose qu'à un moment donné la Terre était entièrement fluide et, deuxièmement, si l'on suppose qu'elle a été formée par l'agglomération de poussières cosmiques ou de particules planétaires. Les auteurs exposent brièvement certaines hypothèses thermiques, fondées surtout sur la théorie de la conduction thermique, et présentant la façon la plus plausible de considérer l'état initial de la Terre. L'article souligne brièvement les rapports étroits qui unissent cette question et divers autres problèmes au premier abord absolument distincts : l'âge du système solaire, l'origine des météorites, la formation du relief lunaire, etc...

The complete text of this paper will be published in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Mrs. Dr. Lubimova : Prof. Jacobs and Dr. Allan rightly noted, that whether the Earth was originally molten or not depends largely upon how fast it accreted. Such calculations of the rate of accretion were carried out in the USSR. Dr. Sofronov studied the process of formation of the planets from a dust component of a gas-dust protoplanetary cloud in detail. He used O. Schmidt's formulae for the growth of the Earth (O. Y. Schmidt, *Izv. Akad. Nauk,* USSR, 1950) and took the variation of relative velocities of particles into account. He estimated the time interval required for the formation of the Earth, and found it to be approximately $0{,}23 \times 10^9$ years. Those calculations gave the possibility to calculate the distribution of the initial temperature. The initial temperature was much lower than the melting temperature.

Prof. Urey : I do not believe that the Urey heating mechanisms by means of free radicals can be applied to the melting of the earth, because free radicals are too unstable to be transferred to the accumulating earth without undergoing reaction in the process. If the earth was formed in a high temperature condition, the energy was supplied by the gravitational energy of accumulation, and the time of accumulation was so short that the energy could not be radiated away sufficiently to maintain a low temperature. — Jacobs and Allan refer to current theories for the accumulation from dust or small objects as uniformly requiring low temperature. It seems to me that Dr. Kuiper's model involving condensation or accumulation within a large gaseous protoplanet as presented by him requires a high temperature origin. A modification suggested by Urey some five years ago has been clearly accepted by Kuiper in recent publications so far as I am aware. The escape of silicates and the inert gases from his developing protoplanets presents very great difficulties. Suggestions for the accumulation of a cold earth have come from the Schmidt school of the USSR and from Urey of the USA.

Sir Edward Bullard and *Prof. Wasserburg* also take part in the discussion.

105. — *Dr. Knopoff* presents his paper on The Lateral Temperature Inhomogeneity in a Static Earth.

If a static model for the earth is assumed, gravity anomalies on the surface of the earth define an upper bound for the magnitude of the allowable lateral temperature inhomogeneity. The problem is solved in the inverse manner : we assume an earth model which is composed of two concentric, almost spherical regions, the outer one being an elastic solid, the inner one a fluid region. This model may correspond to the mantle-core picture of the earth or to a model of an earth rigid to a given depth of compensation. These regions are perfectly spherical until a temperature inhomogeneity is introduced in the outer, rigid shell. The elastic equations are seen to have two driving terms : stresses due to the non-uniform thermal expansion of the solid and stresses due to the non-uniform gravitational fields. The gravity anomaly at the surface is computed from the solution to the boundary value problem for the elastostatic situation. Here again there are two assisting effects : the change in the radius vector for a point on the surface and the change in density of matter close to the point of measurement.

An anomaly of the order of 1—2 mgal/degree C is found. This number varies as the physical conditions surrounding the model are changed. From the known gravity anomalies, the requisite distribution of temperature at the top of the mantle may be inferred. This is found to be inconsistent with the usual picture of the heat flow in a static earth.

The complete text of this paper will appear in the *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

Sir Edward Bullard and *Dr. Revelle* take part in the discussion.

106. — *Mrs. Dr. Lubimova* presents her paper on The Earth's Thermal History and its Geophysical Consequences.

1. The Earth's thermal regime is studied from the origin till the present time suggesting different hypotheses on the concentration

of radioactive elements, decreasing with time, the Earth's age, the coefficient of thermal conductivity. As the initial temperature we take that caused by the Earth's heating in the process of its formation from particles of a gas-dust protoplanetary cloud in accordance with O. Y. Schmidt's theory. The distribution of radioactive elements is supposed to be uniform during the first $(1—2).10^9$ years after which they are believed to become redistributed with different concentrations in the crust, mantle and an iron or silicate core.

2. The solution of the equation of thermal conductivity for a sphere is obtained by means of the Green's function method. This way differs from the usually applied Laplace transformations by Lowan, Van Orstrand, Comenetz, Allan. The latter gives very slowly convergent series for temperature. The Green's function is constructed by means of a reflection method, which makes it possible to confine the series to one term and get an analytical expression for the temperature and the heat flow of the Earth in the form of two items having a simple physical meaning. The calculations of temperature taking account of a change of thermal conductivity with depth, were carried out by the hydraulic analogy method on prof. Lukyanov's hydrointegrator in his laboratory.

3. The initial temperature owing to the impact of particles against the surface of the growing Earth and the compression of the interior at the pressure of the growing outer parts was everywhere much lower than the melting temperature given by Uffen.

4. The abundance of radioactive elements in the Earth as a whole is taken equal to the average abundance of such elements in meteorites. This produces a temperature increase up to 4000° C at depths over 1000 km during $(4—5).10^9$ years. The Earth's thermal history represented the secular heating of its interiors, but not the secular cooling. The same conclusions seem to be made by Jacobs and Allan recently.

5. In the temperature field of the Earth two regions may be selected in the course of the whole history, namely, the region of heat escape and a central region inside which all the emitted heat is spent to raise the temperature. The generation of heat below the region of heat escape as well as changes of physical properties of substances there do not influence the heat flow observed near the Earth's surface. The depth of the heat escape region is proportional to $\sqrt{kt}$ where k is thermal diffusivity, t — time. If the value of k is always constant, namely, $k = 0{,}01$ cm²/sec, this depth does not exceed 1000 km now. If $k = 0{,}1$ cm²/sec, the region of escape reaches the boundary of the Earth's core already in 2.10^9 years.

The probable increase of effective thermal conductivity due to a radiative transfer of energy at a great depth does not produce any losses of inner heat, contrary to what has been assumed by Clark. Our calculations show that the thermal conductivity of the Earth's upper layers decreases with a temperature rise and forbids considerable losses of inner heat. The variation of molecular conductivity with a temperature and pressure rise is calculated from Pomeranchuk's formula for thermal conductivity of dielectrics.

6. Despite a continuous heat generation the temperature inside the region of heat escape decreases slowly in the course of the last $(2—3).10^9$ years whereas at depths below 700 km a heating is going on. Such a regime leads to the expansion of the inner part of the Earth and to the compression of the outer one.

7. If we take that the outer layer (the Earth's crust) was enriched by radioactive elements due to their reduction in the Earth's mantle, the appearance of such a layer should lead to a considerable increase of the surface heat flow as against the flow produced by uniformly distributed sources.

The surface heat flow has passed its maximum and has been decreasing in the course of the last $(2—3).10^9$ years. Its present magnitude is concordant with the observed one if the Earth's age is $(4—5).10^9$ years.

8. The Earth as a whole could not melt due to a high pressure in the process of its radioactive heating. A total melting is possible for bodies with much smaller masses than that of the Earth, say, the Moon. Melting of asteroids can take place only in their centres. However, in the upper part of the Earth's mantle the temperature is close to the melting point and this zone can be the location of magmatic sources. This zone does not extend deeper than 700 km, just as hypocentres of deep-focus earthquakes.

9. The distribution of the present temperature in the Earth's core is concordant with the hypothesis on a solid inner core and a liquid outer part of the core suggested by K. E. Bullen and then by Jacobs.

The complete paper will appear in the *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

See also *The Geophysical Journal, Roy. Astr. Soc.*, Vol. 1, No. 2, pp. 115-134, 8 Figs, June, 1958.

Sir Edward Bullard, Prof. Urey, and others take part in the discussion.

B) Tectonophysics

Prof. Rittmann, introducing the session, reminds the audience that *Prof. F. A. Vening-Meinesz* is the rapporteur for tectonophysics. He regrets the absence of Prof. Vening-Meinesz, who has declared that he wants to leave his place to younger research workers. Prof. Rittmann further draws the attention to a recent paper by Prof. Vening-Meinesz : The Geophysical History of a Geosyncline, *Kon. Nederl. Akad. van Wettenschappen, Proceedings,* Series B, Vol. 60, No. 2, pp. 126-139, 1957.

107.— Prof. Beloussov presents his paper On Types and Origin of Folding.

1. In the light of modern data there are no doubts that folding is a secondary phenomenon derived from the vertical oscil-

lations of the Earth's crust. The most difficult problem here is the mechanism linking vertical oscillations with folding.

2. As data on the structure of the folding zones are not sufficient, special structural investigations have been undertaken. The report is based on the preliminary results of these investigations.

3. The division of the Earth's crust during the process of its vertical oscillations into separate blocks is of essential importance for folding. Folding is a reaction of stratified plastic rocks to the differential vertical oscillations of blocks.

4. With regard to the relative complexity of this reaction there are three types of folding to be distinguished (on the kinematic basis) : block-folding, squeezing-folding and compressional folding.

5. The formation of the block-folding is associated with the most simple and direct reflection of the block movements in the stratified rocks.

6. A further complication of the folding structure is caused by the appearance and intensification of the elements of horizontal movement of masses. When the latter takes place only in rocks of the most plastic formation, squeezing-folding originates linked with a flow of the plastic material from one place and its accumulation in another. The following processes participate in the formation of this folding :

a) the horizontal flow of plastic rocks under the effect of the load of overlying rocks,

b) the squeezing out of light plastic rocks from heavier rocks beneath,

c) the forcing of rocks away from anticlines' crests.

7. The compressional folding (morphologically regarded as holomorphic) is related to a horizontal compression of nonhomogeneous and thick formations. The compression may have its causes in : a) a gravitational slipping of the upper part of an elevated block aside and its pressure on the neighbouring lower blocks ; b) the slipping of the upper part of elevating blocks aside as the result of the forcing of rocks away from anticlines' crests ; c) a free gravitational sliding down the slopes ; d) the layers stretching caused probably by the repetition of processes of arching and subsidence of some region.

8. A variety of the causes of the compressional folding have a common basis in the fact that they are all equally related to intensive and contrast vertical oscillations of the Earth's crust. That is why the compressional folding of different origins is located in the same zones (geosynclines).

9. Different origins of the compressional folding make a geologist face the necessity of revealing local causes of folding in each folded region. A further study of the folding problem requires special structural investigations in different folding zones and

modelling taking into account in its technique the basic peculiarities of the natural folding.

Prof. Rutten : I wish to commend the speaker not only for the clear way in which he stressed the importance of vertical movements of the crust for folding, but also for the reason that he gave us a description of the observed facts only. His predecessors Ampferer, Haarmann, and van Bemmelen, in adding geotectonical theories, made it much more difficult to accept the fact that all this horizontal compression in tectonics is primarily due to vertical movements.

Dr. Scheidegger asks for the reason for the vertical movements.

108. — *Prof. Beloussov* presents his second paper, entitled Development of Geosynclines.

1. A geosyncline is determined mainly as a region of a contrast development of intensive oscillatory movements of the Earth's crust. Inside it zones of intensive subsidence alternate with zones of intensive elevation. Besides this, a geosyncline is a place of folding and considerable development of magmatism. All the phenomena taking place in the geosyncline are mutually associated.

2. In their development geosynclines are subordinated to the periodicity of general oscillations of the Earth's crust which is characteristic of the whole globe. Due to this reason there are tectonic cycles and stages in the development of geosynclines.

3. Each tectonic cycle is divided into two stages : during the first one, subsidence is prevailing, during the second one — elevation. A change of the subsidence domination to that of elevation is called by the author a general inversion.

4. The first stage is characterized by basic submarine volcanic activity, basic sills and weak preliminary folding ; on borders between subsidence and elevation zones « deep faults » may originate. Sedimentary formations reflecting the subsidence domination change from the lower terrigenous to the calcareous one.

5. Between the two mentioned stages not only general but also « particular » inversions take place. They are expressed in the formation of new elevations inside zones of the previous depressions. In connection with this a wave-like process is observed in the geosynclines : new « central elevations » expand and grow while the remaining neighbouring depressions move outside in opposite directions and overlap the adjoining zones of the previous elevation. It results in a full or partial inversion of elevations and depressions inside the geosyncline. As the result of the elevation growth, sedimentary formations change from the upper terrigenous to the lagunary and the molasse.

6. During the second stage of the cycle an intensive folding develops and gradually migrates from the axes of « central elevations » outside thus finally embracing the whole geosyncline though having different intensity in different zones. There are natural relations between strike, verge and intensity of folding,

on one hand, and the regime of the Earth's crustal oscillations, on the other.

7. During the second stage magmatism actively develops in the following succession : granite batholithes, dykes, extrusions.

8. The cycle ends in a mountain-building accompanied by the crust splitting and block displacements.

9. In the post-Archean time geosynclines get narrower with each cycle at the expense of platform expansion. Between typical geosynclines and platform states there is often an intermediate « parageosyncline » state.

10. The whole complex of the geosynclines as well as the location, form and history of the geosynclines as a whole testify to the fact that there are no signs of a general horizontal compression of the Earth's crust or of great horizontal displacements. The whole life of the geosynclines is determined by differential vertical movements of separate blocks of the Earth's crust. Such vertical movements develop either as pure ones or as complicated by derivative deformations in the strata. One of these complications is the folding.

The complete text, entitled Fundamental Features of the Structure and Development of Geosynclines, will appear in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

109. — The paper by *M. V. Gzovsky,* Method of Modelling in Tectonophysics, is presented.

1. We consider that tectonophysics is a science on the mechanism of the development of tectonical deformations and faults in the Earth's crust. The object of investigation is tectonical (geological). The problems and the methods of its solution are tectonical (field observations) and physical (laboratory experiments, modelling, theoretical analysis).

2. The method of modelling of tectonical deformations and faults developing in the Earth's crust must be an essential addition to the field tectonical investigations. Despite the fact that the modelling method has been used in the course of the whole history of geology, its main concepts require more work.

3. The results of testing models can be applied in considering natural geological phenomena only in the case if the models meet the similarity conditions. If these conditions are deduced theoretically and materials for making models with prescribed properties are selected, then it is proposed that our equation system should be used here. These equations describe both the development of elastic and plastic deformations and the formation of fractures. The newly used instruments make it possible to determine the value of all the coefficients and models contained in the recommended system of equations.

4. To solve many tectonophysical problems a serious importance should be attached not only to deformations and fractures but

also to the stress state of models which had not been investigated until this time.

The study of the stress state of models of geological objects has been begun by us with an optical method. Its application to tectonophysics was made more complicated by the fact that only elastic optically active materials for making models were known while the necessary plastic materials were lacking. At present we have at our disposal plastic optically active materials and special instruments for determining their mechanical and optical properties.

5. The examples presented in the report show that a model test under controlled conditions makes it possible :

a) to analyse the effect of different factors on the folding in the Earth's crust ;

b) to ascertain the way how tectonical faults are distributed in space and what their succession in time is if a certain deformation of the Earth's crust takes place.

6. We use models to study by the optical method :

a) to analyse the effect of different factors on the folding in a deformed part of the Earth's crust to the magnitude of tangential stresses inside it in the region of earthquake foci ;

b) the influence of a type of tectonical deformation and fault magnitude on the shape and volume of an earthquake focus and on the amount of energy emitted from it ;

c) a change in the character of earthquake foci with time in the course of the development of tectonic faults.

All these data cannot be obtained by the investigations of only natural objects. Therefore even approximate information from the models facilitates the development of geological criteria of seismicity.

The complete paper will appear in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

110. — *Prof. J. Tuzo Wilson* presents his paper on Evolution of the Crust and its Rock Associations, using a model globe for demonstration.

Exploration of the ocean floors, measurements of the thickness of the crust and a realization of the true length of earth history have, for the first time, revealed geology in a true perspective and enabled some rates to be measured.

These suggest that the crust has entirely developed from volcanic rocks, basalts from depths of tens of kms and andesites from depths of hundreds of kms and that the continents have grown by the addition of provinces, each of which has proceeded through a cycle of evolutionary stages including island arcs and active primary mountain stages.

Different parts of the earth and different stages in the cycle of mountain building have given rise to different rock associations, each marked by characteristic facies of sedimentary rocks, kindred of igneous rocks and extent of metamorphism. These are summarized in Table 1.

TABLE 1.

Stage Mountain cycle	Association	Igneous Kindreds	Sedimentary Facies	Extent of Metamorphism	Location
—	Oceanic	Olivine Basalt	a. Reef limestone (modified platform) b. Abyssal	Local	Ocean basins
0	Borderland	—	Deltaic (modified platform)	Negligible	Continental shelves, deltas
1	Island Arc	a. Andesite b. Spillite c. Ultrabasic	Greywacke	Important	Island Arcs
2	Active primary mountain	a. Plutonic b. Ultrabasic c. Post-orogenic	—	Very important	Active primary mountains
3	Piedmont	Olivine and quartz flood basalts	Arkose	Local	Continental side of primary mountains, Intramontane valleys.
4	Continental	Minor alkaline volcanics	Platform	Local	Covered shields

The whole paper is to be published as part of a book entitled «Physics and Geology», by chapters 11-16. The book is being published by McGraw-Hill in 1958 and the authors are J. T. Wilson, J. A. Jacobs, and R. D. Russell. A comprehensive abstract entitled Geophysics and Continental Growth by J. Tuzo Wilson will appear in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

111.— Prof. Glangeaud reads his paper on Classification géodynamique des différents types de chaînes plissées et origine des déformations.

L'auteur montre qu'il existe quatre catégories principales d'orogènes : 1) orogènes monoliminaires péricontinentaux, 2) orogènes biliminaires, 3) orogènes du type médio-atlantique, 4) orogènes intracratoniques.

Les mécanismes de déformation de la croûte terrestre et les phénomènes tectonophysiques correspondants peuvent être différents pour chacune de ces catégories. Les théories orogéniques doivent tenir compte de la cinématique et de la dynamique des plis pour chaque type de chaînes (orogènes).

Comme exemple, l'auteur décrit l'évolution tectonophysique de chaînes monoliminaires péricontinentales (Japon, Californie, Arcs insulaires) et d'une chaîne biliminaire (Alpes). Il montre l'intérêt des chronodiagrammes orogéniques.

112.— Prof. Fairbridge presents his paper on Statistics of Non-folded Basins.

On a series of maps covering every continent (or major sub-continental unit), the fundamental structural divisions of shield, fold belt and basin have been delineated. A distinction is made between the « platform », as a subdivision of the shield category, being a unit of rigid basement but covered by thin sheets of sediment not exceeding about 300 m. Such accumulation can either be explained as alluvial, eolian or glacial, or as due to eustatic marine invasion. These regions are sometimes included in « basins », which is a misleading procedure since the latter are characterized by varying degrees of basement mobility and thus sediment thicknesses exceeding 300 m.

« Non-folded basins » are taken to be those free from « alpino-type » folding. Folds of lesser order, such as those due to basement faulting or minor gravitational adjustment, may be present, but metamorphism is absent and a clear interpretation of the sedimentary characteristics, notably facies and thickness, may be obtained.

Statistical treatment shows that basins of each broad category tend to repeat the same dimensional characteristics. Categories identified in this way correspond fairly well to the « parageosynclines » (of Stille) and the subdivisions recognized by Kay. It is suggested that each category corresponds to an underlying crust of specific thickness and mobility characteristics.

The complete text of this paper will appear in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

113.— Dr. Heezen reads the paper by *M. Ewing, B.C. Heezen,* and *J. Hirschman :* Magnetic Anomalies and Seismicity in the Mid-Atlantic Ridge and its Extensions.

A median rift has been shown to be a characteristic feature of many topographic traverses of the mid-Atlantic Ridge and its extensions into other oceans. Within the limits of accuracy of epicenter location, the epicenter belt coincides with the rift. A characteristic magnetic anomaly also coincides with the rift and has proven to be an excellent indicator of the crest of the mid-Atlantic Ridge.

An explanation is suggested in which the observed anomaly is accounted for in terms of the distribution of magnetic susceptibility within the crust.

Reference is made to a paper by B. C. Heezen, M. Ewing, and E. T. Miller : Trans-Atlantic Profile of Total Magnetic Intensity and Topography, Dakar to Barbados, *Deep-Sea Research,* Vol. 1, pp. 25-33, 5 Figs, 1953.

The session is closed.

SEVENTEENTH SESSION

THURSDAY, SEPTEMBER 12 (morning)

Program

9. — Scientific communications : On the Fault Plane Work.

114. — *P. Byerly :* Fault Plane Studies.

115. — *V. I. Keilis-Borok :* Investigation of the Earthquake Mechanism.

116. — *V. I. Keilis-Borok :* The Dynamical Methods of Investigation of the Earth's Internal Structure and Crust.

117. — *A. R. Ritsema :* On the Focal Mechanism of Southeast Asian Earthquakes.

118. — *F. Press:* Elastic Wave Radiation from Faults in Ultrasonic Models.

119. — *H. Honda :* The Mechanism of Earthquakes.

120. — *P. Caloi, D. Di Filippo,* and *L. Marcelli :* Meccanismo all'ipocentro del terremoto profondo del 14 Agosto 1950.

121. — *J. H. Hodgson :* The Null Vector as a Guide to Regional Tectonic Patterns.

122. — *D. B. McIntyre* and *J. M. Christie :* Kinematics of Faulting from Seismic Data.

123. — *H. Benioff :* Circumpacific Tectonics.

124. — *P. St. Amand :* Circumpacific Orogeny.

125. — *C. H. Dix :* Mechanisms of Faulting.

126. — *R. E. Ingram :* Statistics and the Fault Plane — a Conjecture.

This symposium has been organized by *Prof. Hodgson.* The session is opened at 09.00 a.m. with Prof. Hodgson as chairman. The complete texts of the papers presented during this symposium will be published in the *Publications of the Dominion Observatory,* Ottawa, Vol. XX, No. 2. Only abstracts of the papers will be given below.

9. Scientific communications : On the Fault Plane Work

114. — *Prof. Byerly* reads his paper on Fault Plane Studies.

The various methods of approach are mentioned. Nakano's theoretical development, following Stokes, emphasizes the effect of large distance. If one concentrates on what happens at the fault he loses sight of the fact that, although where the fault breaks the motion is greatest and of opposite sign on the two sides of the fault, at large distance along the fault plane prolonged the elastic wave motion from the two sides interferes destructively. This is theoretical. Whether the earth's crust is sufficiently homogeneous to allow effective interference is another matter.

Reference is also made to P. Byerly : Nature of Faulting as Deduced from Seismograms, *Geol. Soc. Amer.*, Spec. Paper 62, pp. 75-85, 3 Figs, 1955.

115.— Dr. Keilis-Borok presents his paper on Investigation of the Earthquake Mechanism.

1. The determination of dynamic parameters of the earthquake foci (the mechanical character of rupture in the source ; the fault plane orientation ; the direction of the movement) was made by the method described in the 1954 Assembly publications. It is, in principle, near to the Byerly method and that of the Japanese seismologists (see the report by Byerly at the present symposium). The main feature of the method is the use of S waves (which makes the obtained results single-valued and drastically reduces the number of necessary observations) as well as the ratios of displacement amplitudes in different waves.

Here are the main concrete methodical results achieved within recent years.

a) Simple methods excluding the influence of discontinuities on the shape of the observed waves have been worked out.

By studying the earthquake mechanism, displacements in the « primary » waves are determined (i. e. displacements which would be observed at the so-called « straightened » rays in a homogeneous medium, the focus being the same). Many waves (refracted and reflected at incidence angles exceeding the critical ones, head waves, etc.) differ from the primary ones by displacement shape, number and comparative amplitude of extrema, periods, etc. Usual methods do not make it possible to determine even the signs of the primary waves. However, all possible variations of a displacement shape can be presented theoretically in the form of a set of « standard curves » (see the report « The dynamical methods of investigation of the Earth's internal structure and crust » by the same author). By analyzing these curves one can find and take into account a change in the displacement shape in determining the sign of a primary wave. Especially rapid is a change in the shapes of S waves in near earthquakes.

b) A graphical method has been worked out which with the help of the Wulf's stereographic projection makes it possible do determine the direction of the « straightened » rays (tangential to the seismic rays in the hypocentre) if there are refracting boundaries of any number and shape.

c) Additional theoretical grounds are given to the commonly used substitution of the focus for a multipole (as a rule, it is a dipole with a moment). This multipole is determined as an approximated similarity to a volumetrical source, in which the forces or initial motions are distributed as in a modelling focus. The substitution of forces or initial motions produces equivalent results. The dislocation theory (according to Love), in the way it was used by Nabarro in mechanics, is not applicable directly to the modelling of foci. Its correct application yields the same results as the above theory of volumetrical sources. Investigations have been made of the models of combined movements (a shift and a break-away ; a non-symmetrical shift, etc.).

d) The methods were tested at the example of the earthquake with a surface focus (the White Wolf fault) in Kern County. The focus was studied by a geological observation of the earthquake effects. Interpretation results differ from geological ones by not more than 15—20°.

2. Determinations have been made of the mechanism of 300 earthquakes in the main seismically active zones of the USSR and the adjoining regions : the Western Pacific (from the Marianne Islands to the Aleutian Islands), the Hindu-Kush, the Pamirs and Tien-Shan, Kopet-Dag and Western Turkmenia, the Caucasus. Of special interest is the Garm region (on the border of the Pamirs and Tien-Shan) where about 150 weak earthquakes were studied on a small space.

The basic properties of dislocations in the foci of each zone have been found and compared with tectonics in general.

a) In some regions one dislocation strike prevails in foci and it is approximately longitudinal or transverse regarding the strike of the main structures. In most zones there are two strikes to be distinguished : longitudinal and transverse, the foci with transverse faults being usually more numerous.

b) The dislocations with intensive horizontal components of the movement and with a transverse strike are more frequent in foci than in the main structures. In some cases it goes in line with the neotectonic data.

c) Vertical movements in the foci of some regions are characterized by the fact that during earthquakes a fault wing facing a tectonic depression is lifted up in the foci. This is concordant with geological and geophysical evidences on the movements in the surface foci in Japan ; vertical movements during earthquakes are directed towards the opposite side from the secular ones.

3. The data obtained are of interest for deep tectonics, its relation with seismicity, etc. It is necessary to investigate the greatest number of foci in different tectonic regions. In connection with this, of paramount importance is an international exchange of methodical results and experimental data which has got right in the recent time.

In this connection reference is made to a recent, very comprehensive account of the Russian work in this field : Studies of Earthquake Mechanism (in Russian), *Akad. Nauk USSR, Geophysical Institute,* No. 40 (166), 148 pp., Moscow 1957. The authors of the various articles are O. D. Gotzadze, V. I. Keilis-Borok, I. V. Kirillova, S. D. Kogan, T. I. Kuchtikova, L. N. Malinovskaya, and A. A. Sorsky.

See also *Annali di Geofisica,* Vol. X, pp. 105-128, 1957.

116.— The second paper by *Dr. Keilis-Borok* has the title The Dynamical Methods of Investigation of the Earth's Internal Structure and Crust.

1. To study dispersions and magnitudes of Rayleigh and Love

waves in a many-strata medium one can leave very extended solutions of elasticity theory equations and analyze the structure of boundary conditions.

By means of such an approach the qualitative theory and the methods of computing dispersion and resonance of the above waves are elaborated when the source is asymmetric (so that the waves of both types are generated simultaneously). The dispersion surface computed for a three-strata model of the Earth's crust makes it possible to determine by the dispersion of Rayleigh waves the thickness of the granite and basalt layers separately. If the granite layer is thin the curve of group velocities may have another medium at high frequencies which complicates the structure of the most intensive motions.

2. The shape and direction of surface displacements depend on the ratio of the falling wave length to the thickness of the surface layers (as well as on elastic properties of the layers). This dependence is the consequence of a complex interference of many waves reflected in the surface layers many times.

The interference law can be coded in zero-one numeration so that the influence of the surface layers on the shape and direction of motions can be computed on a unique programme.

These calculations can be used to characterize the properties of the surface layers when the shape and emergence angle of P and S waves of various periods are known.

3. By using a stereographic projection (the Wulf's one) one can build a three-dimensional field of isochrones and isolines of anomalies in azimuths and emergence angles of seismic rays when the medium contains the boundaries—of any number and curvature. By means of these isolines or special stereographic nomograms one can solve the inverse problem — to determine the existence, incline and strike of the boundaries under a seismic station and less accurately — a velocity ratio at these boundaries. As initial data may serve azimuths to the epicentre and emergence angles determined by displacement amplitudes from usual observations at seismic stations.

Under some stations of the Caucasus an inclined boundary is found which seems to be the base of a sedimentary layer covering the granite layer.

4. A theoretical seismogram (displacement U as a time function) for refracted, reflected and head waves in a many-strata medium can be built rather simply by means of the formula

$$U = \frac{A}{R} \Phi (t, \varphi),$$

where A and φ depend on the wave type, asymmetry of the source and ratio of elastic constants on the boundaries passed by the wave. They are computed by means of tables of coefficients of reflection and refraction of plane waves. R depends on angles of incidence and layer thicknesses and indicates the damping caused by a space increase of the wave front. $\Phi (\varphi, t)$ connects the displacement form with that of the initial impulse and is set as a family of « standard curves » with the parameter φ. The same family may be used in any wave type and for any number of layers.

Analyzing theoretical seismograms together with the records of near earthquakes, it is possible to distinguish by dynamical properties (comparative magnitude and displacement form) waves which can hardly be identified by arrival times (exchange waves, head waves arriving next to the direct ones, etc.). By singling out these waves one can more precisely determine the structure of the Earth's crust. For example, in two regions of Central Asia significant deviations of the crustal thickness from the average for the whole region have been determined.

This paper will appear in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

117. — The paper by *A. R. Ritsema,* On the Focal Mechanism of Southeast Asian Earthquakes, is read in title only.

With the help of the initial motions of longitudinal waves the only two possible positions of the fault plane in the earthquake focus are determined.

S waves are then used to determine which of these two positions represents the actual fault plane. For that purpose the direction of polarization of the S wave is plotted as a vector at the appropriate place in Wulf's stereographic projection net. Theoretically all vectors must be oriented along meridional lines that intersect at the point representing the actual direction of fault displacement.

The actual sense of initial motion of the S wave (which is very difficult to ascertain) is not implicitly needed, it is sufficient to determine the direction of polarization of the wave. This direction can be determined everywhere in the S wave train.

It follows that SKS waves are practically useless for the purpose, and that reflected transverse waves are of a very limited value.

The determination of the direction of fault displacement in more than 60 earthquakes of the seismic zones of the SE Asian and the N. Australian continents shows that :

1. in the great majority of earthquakes the fault displacement took place in a direction perpendicular to the seismic zone ;
2. the great majority of the earthquakes of the shallow group (0-0.02 R) is of the mainly transcurrent fault type, and about half of the deeper earthquakes is of the mainly normal fault type ;
3. if we assume that the direction of maximum pressure is making an angle of 30° with that of the fault displacement, most of the maximum pressures in the shallow group (0-0.02 R), and most of the minimum pressures in the deep earthquake group (0.03-0.11 R) were acting about horizontally and perpendicular to the seismic zone ;
4. in general the earthquake-generating stress systems are clearly connected with the local direction of the seismic zone ;

5. the fault plane does not have a preference for the steeper dipping nodal plane for longitudinal waves in the focus and that therefore it is unlikely that density differences in the fault rock are the primary cause of the earthquakes of the region.

Reference is made to the following papers by A. R. Ritsema :

1) Earthquake-Generating Stress Systems in Southeast Asia, *Bulletin of the Seismological Society of America,* Vol. 47, No. 3, pp. 267-279, 5 Figs, July, 1957.

2) The Mechanism in the Focus of 28 South-East Asian Earthquakes, *Lembaga Meteorologi dan Geofisik, Djakarta, Verhandelingen,* No. 50, 72 pp., 33 Figs, 1956.

3) The Direction of Fault Displacement in SE Asian Earthquakes, *Lembaga Meteorologi dan Geofisik, Djakarta, Verhandelingen,* No. 52, 32 pp., 35 Figs, 1957.

118. — *Prof. Press* presents his paper on Elastic Wave Radiation from Faults in Ultrasonic Models.

An ultrasonic model of an impulsive strike slip fault is used to study the radiation pattern of compressional and shear waves. Variations of direction of initial motion and spectrum of compressional and shear waves with azimuth are described. The behavior of the compressional wave follows the classical theory for radiation from a dipole source. The behavior of the shear waves is anomalous in that significant motion occurs where nodes are expected. The relation of this work to current practices in obtaining fault plane solution is discussed.

119. — The paper by *H. Honda* on The Mechanism of Earthquakes, is read in title only.

A brief account on the development of the knowledge on the mechanism of the earthquakes since about the year 1930, is given in this report.

There are two kinds of prevailing hypotheses as to the earthquake mechanism. In one of them, a couple of two equal and opposite forces with moment is supposed to act at the focus of the earthquake, while in the other one a set of two couples of forces with moment which are perpendicular to each other is assumed. We will call the former the force system of the type I, and the latter that of the type II. A set of two couples of forces of the nature of pressure and tension which are perpendicular to each other, and the radial force proportional to $\sin 2\theta \cos \varphi$ in spherical coordinates, are equivalent to the force system of the type II.

The distribution of the direction and magnitude of the initial motion of the P, S and ScS waves of the near deep and intermediate earthquakes, observed in Japan, can be explained by the theories based on the assumption that the force system of the type II acts at the origin in an infinite elastic solid. The directions of the pressure of the stresses causing the earthquakes seem to be directed perpendicularly to the trends of the deep and intermediate earthquake zones in and near Japan. For the investigation of the P, S and surface waves and the deformation of the earth's surface observed in the cases of very shallow earthquakes occurring in Japan, the theories for the force system of the nature of the type II or the radial force proportional to sin 2φ in cylindrical coordinates, acting at the origin on the surface of a semi-infinite elastic solid, have been applied.

The stereographic projection methods which are appropriate for the investigation of the earthquake mechanism based on the observations at the stations distributed over the world, have been proposed and developed by P. Byerly and J. H. Hodgson, and applied to the studies of numerous earthquakes by many seismologists, the force system of the type I being assumed as the basis of the investigation. The plane bisecting the couple of forces is considered to be the fault plane. The relations between the strikes and dips of the fault planes, the motion directions along the fault planes and the geological features, are investigated.

According to the theories on the elastic waves, the patterns of the initial motions of the P waves for the force systems of the types I and II, are the same in both cases. As the differences of the effects of the force systems are to be noticed in the patterns of the S waves, it is desired that the S waves observed at the distant stations may be investigated further in detail.

The complete text of this paper has appeared in *The Science Reports of the Tôhoku University,* Series 5, Geophysics, Vol. 9, Supplement, 46 pp., 60 Figs. 122 Ref., July, 1957.

120. — The paper by *P. Caloi, D. Di Filippo,* and *L. Marcelli,* Meccanismo all'ipocentro del terremoto profondo del 14 Agosto 1950, is not presented.

A paper entitled La natura fisica all'ipocentro del terremoto profondissimo dell'Argentina settentrionale (14 Agosto 1950), by D. Di Filippo and L. Marcelli, has appeared in *Annali di Geofisica,* Rome, Vol. X, No. 3-4, pp. 221-234, 9 Figs, 1957.

121. — *Dr. Hodgson* presents his paper on The Null Vector as a Guide to Regional Tectonic Patterns.

La détermination des plans de faille, qui ne repose que sur les ondes P est indéterminée en ce sens qu'on obtient deux plans sans qu'on sache lequel représente la faille. L'intersection des deux plans, toutefois, est particulièrement bien définie. Quel que soit le plan représentant la faille, la ligne d'intersection est perpendiculaire au couple de déplacement ; cette ligne porte l'appellation vecteur zéro (null vector).

Dans une communication antérieure, on a montré que dans plusieurs régions, le vecteur zéro est parallèle à des plans fortement inclinés qui ont la même direction que les accidents géographiques qui s'y rattachent. Le présent mémoire présente un résumé de toutes les solutions disponibles et cherche à établir si cette propriété du vecteur zéro trouve une application générale.

122.— Prof. McIntyre presents the paper by *D. B. McIntyre* and *J. M. Christie :* Kinematics of Faulting from Seismic Data.

The attitude of a fault and the nature of the slip on it can be determined from the pattern of distribution over the globe of compressional and dilatational first motions of P waves. The method, which is due to Byerly and Hodgson, gives two possible solutions for each earthquake. The writers have already shown that in a homogeneous tectonic area the ambiguity might be resolved by consideration of the geometrical relations between the pairs of solutions: it was concluded that in the S. W. Pacific the movement was on steep strike-slip faults striking parallel to the physiographic feature. In the present paper a similar analysis is attempted of a sequence of Greek earthquakes.

On the assumption that the ambiguity of the results of a P wave analysis can be resolved by study of the first motions of S waves, Kogan has derived solutions for the N. W. Pacific from data obtained at stations within the U.S.S.R. It is shown that Kogan's results for the Japan-Kamtchatka arc differ markedly from Hodgson's solutions for the same region and time interval based on P wave records obtained at stations distributed over the world.

The current techniques using S waves are criticised, and the status of seismic methods for determining the orientation of fault planes and the nature of the slip on them is reviewed. The significance of the results in relation to tectonic theory is discussed.

123.— Prof. Benioff presents his paper on Circumpacific Tectonics.

A study of the Kamtchatka aftershock sequence by Markus Båth and Hugo Benioff provided the basis for distinguishing between the two possible fault plane solutions for the principal shock given by Hodgson. Thus, this great earthquake was generated by a right-handed slip on a 1000 km fault segment lying parallel to the trench. With this observation, data are now available for the direction of slip on the shallow components of nearly all the principal circumpacific faults. This includes Japan, Philippines, Tonga-Kermadec, New Zealand, the Aleutian Arc, Alaska, Northwest Pacific, California and possibly the western coast of South America. In all of these regions the principal fault lies parallel to the coast and the slip is right-handed. Secondary faulting such as represented by the Garlock fault in California, strikes transverse to the coast line and in many cases is left-handed. Although the principal movement is strike slip in nature, smaller dip slip components also occur and these are responsible for the relief which takes the form of oceanic deeps and associated mountain ranges. The circumpacific tectonic activity now in progress can thus be described as a tangential, clockwise rotation of the continental margins relative to the oceanic mass, together with a radial movement of the margins toward the oceanic mass. If the tangential slip is constant around the margins and equal to that of the San Andreas rate, the time for a complete revolution is approximately 3×10^9 years.

124.— Dr. St. Amand reads his paper on Circumpacific Orogeny.

The Pacific Coast of North America is fringed by a series of right lateral faults sub-parallel to the Coast line. The San Andreas fault extends from Baja California to a point off the Oregon-Washington Coast. Near this point, the Alaskan fault complex begins and continues past the Queen Charlotte Islands, along the coast and inland to join the Denali fault. This zone of faulting extends for more than 2100 km from Lynn Canal, by the north face of Mt. McKinley, to the Bering Sea.

Faulting on the Alaska Peninsula having the trend of the Aleutian Island Arc has been mapped as right lateral faulting with concommitant overthrusting.

First motion results from seismology indicate that movement along the Aleutian Arc, the Kamtchatka-Kurile Arc and elsewhere around the Pacific may be aligned parallel to the strike of the island arcs or mountainchains, and is often of right lateral sense.

The conclusion is presented that the Pacific Basin from at least Baja California to a point beyond the Kurile Islands is rotating counterclockwise. The rest of the Pacific Basin is probably also rotating in the same sense.

The Rocky Mountain Trench and sub-parallel features between it and the coast indicate that this type of movement has been going on a very long time and represents a fundamental type of orogeny.

The results of field and structural geology at this stage of our knowledge support the basic work of Byerly and of Hodgson and aid in defining the nature of circum-pacific orogeny.

125.— Prof. Dix presents his paper on Mechanisms of Faulting.

The faulting picture shown by E. M. Anderson in his book using C. E. Inglis' stress calculations is examined, and it appears difficult to extract energy for radiation in seismic waves from such a picture. Before and after the formation of such a crack the stress energy appears to be the same.

However, if there are two pre-existing « lubricated » approximately co-planar sheet regions or sheet regions weaker than their surrounding rocks with a strong solid region between them, then this solid between may be ruptured and energy radiated. This may be modified to include the growth of a simple single lubricated crack but this later process does not seem adequate for large earthquakes.

126.— Father Ingram gives his paper on Statistics and the Fault Plane — a Conjecture.

The paper is a note pointing to the possibility that statistics may be used to give the best position of the boundaries separating compressions from dilatations in fault plane solutions. Tentative solutions are given for two simple cases, where separation is in terms of a single straight line, and where it is in terms of two straight lines. In each case a discriminating function is used to determine the best equation of the lines.

The session is closed.

MEETING OF THE COMMITTEE
OF
THE INTERNATIONAL SEISMOLOGICAL SUMMARY
THURSDAY, SEPTEMBER 12 (afternoon)

The session is attended by the following persons : Miss Lehmann, Mme Kondorskaya, Sir Harold Jeffreys, Prof. Gutenberg, Dr. Stoneley, Prof. Bullen, Mr. Murphy, and Dr. Hodgson.

The session is opened at 01.45 p. m. with *Sir Harold Jeffreys* as chairman.

The main problems discussed concern compilation of the I. S. S. and finance.

1. Compilation of the I.S.S. It is agreed that preparation of the I. S. S. would be facilitated if stations would send in their data to the I. S. S. on cards of a standard form, to be drawn up by the Assistant Director of the I.S.S., Mr. J. S. Hughes. It is mentioned that, when possible, information about earthquake magnitudes should be sent in, and duly printed in the I. S. S. (see further Resolution 6 in Appendix 1).

2. Finance. Reference is made to the acute financial difficulty under which the I. S. S. is compiled and published. It is agreed that the following resolution should be presented to the Association and, when approved, forwarded to the Secretary General of the Union: « For the satisfactory preparation of the I. S. S. it is considered essential that an annual sum of 10.000 U. S. dollars should be provided from international sources. » (see further First Session and Resolution 1 in Appendix 1).

The session is closed.

EIGHTEENTH SESSION

THURSDAY, SEPTEMBER 12 (afternoon)

Program

9.— Scientific communications : Gravity Anomalies ; Isostasy (cont.).

127. — *J. Goguel :* L'influence des failles et des autres irrégularités de l'écorce sur la compensation isostatique dans l'hypothèse de la régionalité.

128. — *E. N. Lyustikh :* Deep Crustal Structure of Indonesia from Gravity Data.

129. — *G. D. Garland :* The Earth's Crust in the Canadian Cordillera as Indicated by Gravity Measurements.

130. — *H. W. Oliver :* Gravity Studies of Crustal Structure Associated with Sierra Nevada, California.

131. — *C. Tsuboi :* Reconnaissance of Gravity Distribution along Continental Margins.

This is a continuation of the Thirteenth Session and is held together with the Association of Geodesy. It is opened at 01.55 p. m. by *Dr. Båth.*

9. Scientific communications : Gravity Anomalies ; Isostasy

127. — *Mr. Goguel* reads his paper on L'influence des failles et des autres irrégularités de l'écorce sur la compensation isostatique dans l'hypothèse de la régionalité.

Afin de serrer de plus près la réalité géologique, le schéma de Vening Meinesz, assimilant l'écorce à une dalle élastique flottant sur un magma plus dense, est repris en envisageant l'éventualité de failles, pouvant être oblique (extension ou compression), et permettre, outre le rejet vertical, un pivotement relatif de leurs lèvres. Pour permettre de combiner la compensation isostatique du relief, avec le jeu de telles failles, il est commode de dissocier les densités en deux répartitions, l'une fixe, de 2.67 sous le géoide et zéro au-dessus, l'autre correspondant au complément, de telle sorte que, une fois supprimée la surcharge correspondant au relief, le jeu des failles ne réintroduise pas un nouveau relief. On constate que le fait que les failles aient joué se traduit par une modification de la position de l'écorce, donc par des anomalies gravimétriques calculables en fonction des composantes du rejet et du degré de régionalité ; de telles anomalies ne doivent pas être considérées comme traduisant un défaut d'équilibre isostatique.

On aborde également l'étude des relations entre le jeu des failles et le système de contraintes régnant dans l'écorce.

Application au cas des fossés africains, des horsts entre fossés ; des Alpes autour de la Plaine du Pô.

The complete paper will be published in *Annales de Géophysique*, Paris.

Mr. Lagrula : J'approuve l'esprit de cette communication (explication d'anomalies par un perfectionnement du schéma isostatique, au lieu de considération de déséquilibres). Je voudrais insister sur un défaut essentiel du schéma d'Airy = une seule discontinuité et non pas deux comme montre la séismologie (schéma de Gutenberg). — J'ai calculé que l'action de la « couche intermédiaire » peut être très importante pour certaines structures (littoraux abrupts ou fosses océaniques profondes = 50 milligals et davantage).

Cependant, après avoir été un ardent défenseur de l'hypothèse de l'équilibre isostatique, je viens de trouver contre la perfection de cet équilibre un argument très important = au Sahara, dans des régions très vastes (par exemple 500.000 km^2) et peu tourmentées, l'anomalie garde une valeur de même signe. Pour de telles régions, aucun schéma n'assurera un équilibre parfait.

Mes points de vue ont été présentés dans une série de notes (*C. R. Académie des Sciences,* Paris) ces dernières années.

Dr. Cook : I think that isostatic anomalies are not the most useful or effective way of studying the structure of the crust in regions such as the Po Valley. The necessary modifications to the scheme of regional compensation that M. Goguel has shown to be necessary, make the computation of isostatic anomalies complicated. The method of Bullard and Cooper for the deduction of the mass distribution from the Bouguer anomalies seems to me to be more effective. It enables the uncertainty inherent in the data to be defined and involves no extraneous hypothesis. When the mass distribution has been found it can be examined to see if it corresponds with isostatic equilibrium.

There is evidence that in sedimentary basins the faulting of the crust may be on a much smaller scale than is suggested by the scale of elastic bending of the crust, and in these circumstances, the direct deduction of the mass distribution from the gravity observations seems to be more satisfactory.

Dr. Båth hands over the chair to *Mr. Goguel.*

128. — The paper by *E. N. Lyustikh,* Deep Crustal Structure of Indonesia from Gravity Data, is read in title only.

The complete paper has been published in Russian in *Trud. Geofys. Inst. Akad. Nauk SSSR,* No. 26 (153), pp. 160-197, Moscow, 1955.

129. — *Dr. Garland* presents his paper on The Earth's Crust in the Canadian Cordillera as Indicated by Gravity Measurements.

Les données gravimétriques recueillies dans la Cordillère canadienne et dans les régions voisines permettent, semble-t-il, d'attribuer à deux causes l'anomalie négative apparente qu'on y observe : l'épaississement de la croûte dans l'ensemble de la région et la densité relativement faible du granite qui se présente en masses intrusives considérables dans la chaîne du littoral. L'interprétation du champ de la gravité peut se compliquer davantage du fait de l'influence de structures plus anciennes (précambriennes) non disposées parallèlement aux systèmes de montagnes. Ces structures plus anciennes peuvent toutefois faciliter la mesure des déplacements horizontaux dus aux poussées orogéniques.

The complete text is published as follows :

1) The major part has been published under the title Investigations of Gravity and Isostasy in the Southern Canadian Cordillera, by G. D. Garland and J. G. Tanner, *Publications of the Dominion Observatory,* Ottawa, Vol. XIX, No. 5, pp. 169-222, 1957.

2) The remainder of the work is planned for publication in the *Bulletin of the American Association of Petroleum Geologists.*

Dr. Cook : Dr. Garland's paper is valuable as showing the importance of knowing the densities of surface rocks in interpreting gravity anomalies. — I should like to ask Dr. Garland if his results are compatible with the granite bodies extending to the depth of the crust. Prof. T. Murphy and I thought this possible in Ireland if the density of the granite should increase with depth. — At the risk of introducing a controversial point, it seems to me that the fact that granite is less dense than the surrounding material, implies on thermodynamic grounds that it could not have been derived from the county rock by metasomatism but must have been implaced mechanically.

Prof. Slichter expresses gratification for the interpretation in terms of geologic structures and asks 1) What is the value of density for « denser rock » in last slide ? and 2) On what basis was the value of 0.5 in density difference adopted ?

Prof. Tsuboi : If we wish to investigate gravity anomalies in detail quantitatively, I believe we must be very careful about the value of the vertical gradient of gravity. This quantity varies in association with gravity anomaly itself, and the variation may easily reach several per cent of its normal value, 3086×10^{-9}.

Dr. Garland : In reply to Dr. Cook, the depth extent of the igneous bodies would be considerably altered if the density of the granite increases with depth. — The density difference 0.5 is the difference 3.2 — 2.7. Prof. Woollard apparently used a value of about 0.5 to bring the depth to the Mohorovičić discontinuity in agreement with the seismic results in the USA. — With regard to magnetic observations, these are available over the plains, and show a good correlation with the gravity anomalies. — Dr. Tsuboi pointed out the effect of an incorrect free air reduction on the anomalies. It is true that this is a possibility, but we have studied the correlation of anomalies with height and do not believe that the error is serious.

130. — *Mr. H. W. Oliver* presents his paper on Gravity Studies of Crustal Structure Associated with Sierra Nevada, California.

The Sierra Nevada affords an excellent site for gravity studies of crustal structure. This mountain range is 400 miles long and 80 miles wide and culminates in Mt. Whitney (14.496 ft.), the highest point in the United States. The rocks now exposed at the surface are largely granites of Cretaceous (?) age, which have very little near-surface density contrast to camouflage possible gravitational effects due to crustal structure. Moreover, recent seismic studies of the earth's crust in California provide control for resolving the inherent ambiguities of gravity interpretation.

Fifteen hundred gravity stations occupied in the Sierra show a range in complete Bouguer anomalies from —20 mgal at the western edge of the Sierra to a minimum of —240 mgal just west of the Sierra crest, a distance of only 65 miles. Farther east, a positive regional gradient of 1 mgal per mile continues as far as Death Valley. Direct analysis of Bouguer anomalies using seismic data as control indicates that the crust is 30 km thick under the San Joaquin geosyncline ; that the thickness increases gradually to 35 km at the western edge of the Sierra Nevada ; very rapidly in the western Sierra foothills to a maximum of about 60 km under Mt. Whitney ; and that farther east, the thickness decreases to 40 km under Death Valley.

Isostatic anomalies corrected for local geologic effects are very close to zero at the western edge of the Sierra Nevada. The central and eastern regions are overcompensated by 40-50 mgal suggesting that current uplift along the Sierra Nevada fault zone may be caused by isostatic forces. However, there is almost no local isostatic response to the 10.000-foot eastern Sierra scarp or to individual ranges east of the Sierra Nevada.

The paper will be published as follows :

1) A short paper will appear in *Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques, Fasc. N° 20.*

2) A more comprehensive paper is planned to be published later in the *Bulletin of the Geological Society of America.*

Mr. Lagrula : Is there any evidence for a systematic variation of rock density with elevation in the Sierra Nevada ? Would the Airy-Heiskanen corrections using T = 20 km more completely remove the Bouguer anomaly minimum associated with the Sierra Nevada ?

Mr. Oliver : Regarding the first question, over 90 % of the rocks exposed at the surface along the gravity profile through Mt. Whitney consist of biotite-hornblende quartz monzonites of the Sierra Nevada batholith. On the basis of several hundred density measurements, the average density of the quartz monzonites is 2.68 ± .05 and there is no systematic variation in the density of these surface rocks with altitude. The « older » granites that outcrop in the western foothills are slightly more mofic than the « younger » granites of the high Sierra. The age of both series is, presumably, Cretaceous.

It's quite true that isostatic anomalies in the high Sierra would be closer to 0 if computed on the Airy-Heiskanen scheme with T = 20 km instead of T = 30 km. However, I think we should be guided by the results of seismic studies in California which indicate a « normal » crustal thickness of 30-35 km.

Dr. St. Amand : What would be the change in Bouguer and isostatic anomalies in the Sierra Nevada if Jeffreys' spheroid had been used for a reference spheroid instead of the international ellipsoid ?

Mr. Oliver : The effects on gravity anomalies of (1) a correction to observed gravity values for the change in absolute gravity standard from Potsdam to Jeffreys' absolute standard and (2) the difference between the G_0 terms of the international gravity formula and Jeffreys' formula just cancel each other. Therefore, the only change in gravity anomalies would be due to the $\sin^2\varphi$ term. This amounts to —0.2 mgal at a latitude of 35° N.

Dr. Dix : In connection with your rise in gravity well out into the San Joaquin Valley to the west of the Sierra Nevada, I would like to comment that, farther west, Bouguer anomalies fall off again and a gravity minimum is associated with the western part of the San Joaquin Valley.

Mr. Oliver : When accurate densities become available for the San Joaquin Valley sediments down to bedrock, it will be interesting to remove their effect on gravity anomalies. I suspect that geologically-corrected isostatic anomalies in the San Joaquin will be positive by 20—40 mgal, indicating crustal thinning under this geosyncline.

Dr. Fedynsky : In your interpretation of gravity data you suppose that the crust is of homogeneous density. But you may obtain some indications on the existence of the basaltic rocks in the upper layer from gravity anomalies, because your survey (profiles) had enough detail. It would be a very interesting study.

Mr. Oliver: In our interpretation of the Fresno-Death Valley gravity profile, it need not be assumed that the earth's crust is of homogeneous density. The physical assumptions are (1) that there is no lateral variation in the density of the earth's crust at depths below « superficial geologic disturbances » and above the minimum depth to the base of the crust (about 30 km in California) and (2) that the average density contrast between the upper mantle and only that part of the earth's crust which displaces it is 0.43. Any scheme of vertical density stratification within the depth limits of the first assumption is permitted if individual layers do not vary in thickness.

A horizontal basaltic layer of infinite extent and uniform thickness cannot be discerned from gravity studies alone and the results of seismic work on crustal layering in California are, as yet, inconclusive. Basaltic and andesitic flows have been fairly common in the Sierra Nevada throughout Cenozoic time and there are a few small isolated bodies of gabbro which give rise to local gravity anomalies.

131.— Prof. Tsuboi presents his paper on Reconnaissance of Gravity Distribution along Continental Margins.

The extension of the $\frac{\sin x}{x}$ method for gravity interpretation into two-dimensional cases has been made possible by kind cooperation of Dr. C.H.G. Oldham and Mr. V. B. Waithman of California Research Corporation.

With the aid of the numerical tables prepared by them, gravity distributions in several regions along continental margins have been investigated.

The complete paper will be published in *Journal of Physics of the Earth,* Tokyo.

The session is closed.

NINETEENTH SESSION

THURSDAY, SEPTEMBER 12 (afternoon)

Program

9.— Scientific communications : Tectonophysics (cont.).

132.— L. Egyed : Shrinking, Expansion or Magmatic Currents ?

133.— C. S. Beals : Meteorite Craters in Canada.

The session is opened at 04.00 p.m. and is held jointly with the Association of Volcanology in continuation of the Sixteenth Session.

9. Scientific communications : Tectonophysics (cont.)

132. — *Prof. Egyed* reads his paper on Shrinking, Expansion or Magmatic Currents ?

Heat is considered by nearly all geotectonic hypotheses as the most important energy source. Considering the mechanism of transformation of heat into mechanical energy, essentially two different views are known. According to the first mechanical energy is generated by shrinking due to cooling of the Earth, whereas the other one proposes an energy transformation by magmatic currents due to temperature differences existing in the Earth's interior. The first kind of hypothesis involves a volume decrease of the Earth, while the second type postulates no volume change in the course of energy transformation. Consequently, by determining the trend of the volume change it will be possible to confirm one of the above hypotheses or to reject both of them in favour of a third explanation.

The surface of water-covered continental areas, however, indicates, a clearly decreasing trend with geological time, at least in the course of the last 500 million years of the Earth's evolution. This fact may be explained most readily by assuming an expansion of the Earth volume, with a radius increase amounting yearly to 0,5 mm (Egyed, *Geofisica pura e applicata,* Vol. 33, and *Nature,* Sept. 8, 1956).

Consequently, the paleogeographic evidences seem to be strongly in favour of an expanding Earth.

Considering this result the author compares the different explanations of the most important geological and geophysical phenomena from the point of view of shrinking, expansion and magmatic currents, respectively.

The following questions are treated :

1. The secular decrease of the angular velocity of the Earth.
2. The dip of the hypocentral plane of earthquakes.
3. The depth-frequency distribution of earthquakes.
4. The connection between deep-sea trenches and deep shocks.
5. The origin of continental crust and oceanic basins.
6. Explanation of continental drift and polar wandering.
7. Formation of geosynclines and orogenesis.
8. Periodicity of geological phenomena and crustal movements.

It was shown that, whereas clear and simple quantitative explanations may be derived from the expansion, without using any auxiliary hypothesis for the above problems, the explanations on the ground of contraction or magmatic currents are mostly obscure and forced, partly based upon unwarranted auxiliary hypotheses. Moreover, there are problems, which cannot be explained at all by shrinkage or magnetic currents (Egyed, *Geologische Rundschau,* Vol. 46, 1957).

Consequently, the conclusion must be drawn that the most important factor in the evolution of the Earth is expansion and the effects of shrinkage and magmatic currents may be neglected, at least in a first approximation.

The amount of expansion deduced above and the energies involved are so great that it is impossible to derive them from common thermal processes. A possible explanation for the expansion of the Earth's volume and the origin of energies is as follows :

The inner and outer core and the mantle of the Earth form three phases of an essentially homogeneous silicic mass. However, the inner phases are unstable and suffer a continuous decomposition towards the outermost phase. The decomposition involves a decrease of density, resulting in a volume increase of the Earth. The phase transitions between the parts of the core and the mantle are considered to be statistical processes of a long half-life.

It may be shown, that the transition energy per molecule should be about 30 eV, i. e. just within the range of ionization energies. One may think, of course, of a nuclear process of very low energy, but it seems to exist another more plausible explanation. According to some high-pressure experiments of Bridgman it seems possible for any material to possess several stable high-pressure modifications. The formation of these stable high-pressure modifications requires a considerably greater amount of energy than their destruction. If the core is in a « high-energy state » of this kind, thermal agitation of the molecules may cause a statistical decomposition into the normal state. The great energy difference between the formation and the destruction of the high-energy modifications should account for the irreversibility of the process as well.

The results presented in this lecture are partly published in the following papers by L. Egyed :

1) A New Theory on the Internal Constitution of the Earth and its Geological and Geophysical Consequences, *Acta Geologica Acad. Sci. Hung.*, Vol. IV, pp. 43-83, 24 Figs, Budapest, 1956.

2) Determination of Changes in the Dimensions of the Earth from Paleogeographical Data, *Nature,* September 8, 1956, London.

3) The Change of the Earth's Dimensions Determined from Paleogeographical Data, *Geofisica pura e applicata,* Vol. 33, pp. 42-48, Milano, 1956.

4) A New Dynamic Conception of the Internal Constitution of the Earth, *Geologische Rundschau,* Vol. 46, pp. 101-121, 9 Figs, Stuttgart, 1957.

133. — *Dr. Beals* presents his paper on Meteorite Craters in Canada.

La découverte par V. B. Meen en 1950 des caractéristiques météoriques du cratère Chub au cratère du nouveau Québec (Lat. 61°17'N ; long. 73°41'W; diamètre 2.1 miles, profondeur 1,185 pieds) dans le voisinage de la baie de l'Ungava a stimulé l'intérêt pour les cratères météoriques au Canada, et deux nouvelles découvertes en ont résulté à courtes intervalles, le cratère Merewether (Lat. 58°03'N ; long. 64°03'W; diamètre 650 pieds, profondeur 160 pieds) au nord du Labrador et le cratère Brent dans le parc Algonquin en Ontario. Le cratère Brent (Lat. 46°4.5'N; long. 78°29.5'W) d'un diamètre approximatif de 2 miles est rempli de sédiments paléozoïques. Un trou creusé à 570 pieds de profondeur au centre du cratère n'a pas pénétré complètement les sédiments, cependant qu'un autre, près du bord, a révélé une épaisseur considérable de brèches rocheuses qui peuvent avoir été causées par un choc météorique ou une explosion.

Etant donné que les trois cratères sus-mentionnés ont été découverts sur des photographies aériennes, il a été décidé de scruter toutes les photographies aériennes disponibles dans l'espoir d'y faire d'autres découvertes. A peu près 400.000 photographies ont été étudiées et neuf formes circulaires ont été repérées. Tandis que cinq de ces cratères durent être éliminés, ayant eu une autre origine, quatre sont considérés comme ayant eu une origine météorique possible. Jusqu'à ce jour, un seul a été le sujet d'une étude détaillée, celui de Holleford en Ontario (Lat. 44°27'N; long. 76°38'W; d'un diamètre de 1.46 miles, profondeur actuelle de 100 pieds).

Des relevés gravimétriques du cratère Holleford indiquent une dépression dans le roc précambrien remplie de matières plus légères. Une étude séismologique a été moins concluante, mais nous laisse cependant supposer le même résultat.

Trois trous furent ensuite percés à l'aide d'une foreuse à pointes de diamant, à 1,400 pieds, 2,500 pieds et 3,180 pieds du centre à des profondeurs de 1,128 pieds, 1,486 pieds et 443 pieds respectivement. A chacun des trois, le contact entre la couche sédimentaire et ce que nous pouvons raisonnablement présumer être le plancher ou fond du cratère, est distinctement marqué. Dans le trou (1), le fond a été rencontré à 750 pieds de profondeur et dans le trou (2) à 415 pieds. Au trou (3) à la bordure, la surface du cratère a été rencontrée à 70 pieds. La profondeur du plancher pour les deux trous à l'intérieur correspond étroitement à celles prédites par le rapport du diamètre à la profondeur et le profil détaillé d'un cratère de 1.46 miles de diamètre du genre lunaire ou un cratère d'explosion. La profondeur en bordure du troisième trou en tenant compte de la topographie générale de la région, indique qu'une bordure soulevée ayant originellement existé, a été en grande partie érodée avant le dépôt des sédiments.

Sous le plancher du cratère, la carotte consiste en roches moulues et granulées faiblement remaniées. Le trou (2) pénètre une zone de pierre fracassée de plus de 500 pieds. Cette zone est probablement beaucoup plus épaisse vers le centre. Nous n'avons repéré aucune trace de matière volcanique dans aucune des carottes.

La similarité générale que le cratère Holleford présente au cratère météorique Barringer en Arizona, dont l'origine météorique est bien établie, est frappante et dans la forme générale et dans la nature de la matière qui se trouve sous le plancher. Cette analogie suggère un choc météorique comme l'origine la plus probable du cratère Holleford et jusqu'à ce jour aucune autre explication satisfaisante n'a été trouvée.

En plus des cratères sus-mentionnés, qui furent tous repérés sur des photographies aériennes, un autre objet beaucoup plus grand a été découvert à Deep Bay en Saskatchewan par M. J. S. Innes au cours de relevés gravimétriques dans l'ouest du Canada. Ce cratère, qui forme une baie dans la partie sud-est du Lac Reindeer, a de 7 à 8 miles de diamètre et est en moyenne environ 10 fois plus profond que le reste du vaste lac dont il fait partie. D'autres signes d'une origine météorique sont sa forme circulaire remarquable, les restes d'une bordure soulevée et les traces de roches fracassées sur le bord du cratère allant en diminuant à mesure que l'on s'éloigne du centre.

L'expansion de la photographie aérienne à plusieurs vastes régions à travers le monde, a donné l'occasion tout à fait nouvelle d'entreprendre des recherches systématiques à l'échelle mondiale en vue de la découverte de cratères météoriques. Il est donc suggéré que, si les géophysiciens et les astronomes intéressés à ces problèmes prennent avantage de ces opportunités, la vraisemblance d'améliorer considérablement nos connaissances, est bonne.

The material presented has for the most part appeared in the following papers:

1) A Search for Analogies between Lunar and Terrestrial Topography on Photographs of the Canadian Shield, by C. S. Beals, G. M. Ferguson, and A. Landau, *Journal Royal Astronomical Society of Canada,* Vol. 50, pp. 203 and 251, 1956.

2) A Possible Meteorite Crater at Deep Bay, Saskatchewan, by M. J. S. Innes, *Journal Royal Astronomical Society of Canada,* Vol. 51, p. 235, 1957.

3) A Probable Meteorite Crater of Great Age, by C. S. Beals, *Sky and Telescope,* Vol. 16, p. 526, 1957.

Mr. Lagrula : Au Sahara central plusieurs cratères ont été mis en évidence par photos aériennes mais aucune étude d'ensemble n'a été faite.

Dr. Harwood : Assuming that geophysical evidence confirms that the lower part of Hudson Bay is a crater, then it must be very old. Protesazoic sediments rise above the sea surface 70 miles east of the circular shore of the Bay. These are completely folded and are related to sediments equally completely folded on the East Rim. These sediments are in turn overlain by later Protesazoic sediments which are flat lying. They do not however appear on the Belcher Islands. Both series (of sediments) are intruded by basaltic sills and in sedimentary sequence overlain by basaltic flows. In at least two places these flows and sediments are intruded by granites in which blocks of the sedimentary material can be identified. It is suggested therefore that it is possible that the meteor impact disturbed the crustal structure in such a way that such flows reached the surface and that orogeny on the earlier Protesazoic followed the impact. — In any case, the feature is very old and most of it occurred in the Mid-Precambrian.

Dr. Beals : Positive magnetic anomalies are not expected to be marked, since meteoric material would be thrown out of the crater by the explosion. — It is not hopeless to look for craters in areas covered by sediments, as evidence of circular form may survive even though the crater is quite deeply buried.

At the end of the session, outside the program, *Prof. Shneiderov* expresses some personal opinions on the Constitution of the Earth (« The Hearth Hypothesis »).

The session is closed.

TWENTIETH SESSION

FRIDAY, SEPTEMBER 13 (morning)

Program

9. — Scientific communications : Seismic Waves (cont.).

134. — *P. N. S. O'Brien :* Observations of the Surface Motions Caused by an Explosive Source in a Layered Medium.

135. — *Z. Droste :* An Angular Distribution of Energy Density Emitted from a Seismic Focus.

136. — *R. Teisseyre :* An Outline of the Theory of Non-local Seismic Foci.

137. — *J. W. C. Sherwood :* The Displacement Field in a Stratified Solid Medium Due to Localized Impulsive Forces.

The session is opened at 09.00 a.m. with *Dr. Båth* as chairman.

9. Scientific communications : Seismic Waves (cont.)

134. — *Dr. O'Brien* presents his paper on Observations of the Surface Motions Caused by an Explosive Source in a Layered Medium.

A routine seismic refraction line was shot in rather more detail than is usual. The shot-to-station distances varied from about 100 to about 30,000 feet.

In addition to the usual head wave pulses a « multiply reflected refraction » (Officer, 1953) and the dispersive surface waves were observed.

Peak amplitude measurements were made on the head wave pulse from a triassic marl about 80 feet deep. If the amplitude is assumed to decay inversely as the mth power of the distance, the least squares value for m is 2.16 ± 0.04. After applying the theoretical « spread factor » for head waves there remains a residual attenuation of 1.96 ± 0.28 decibels per 1,000 feet. Applying this value to the predominant frequency in the pulse, about 20 c/s, the attenuation coefficient becomes 0.8 decibels per wavelength.

Measurements of the residual attenuation for two limestone layers at depths of about 1,000 feet and 3,000 feet also give values somewhat less than 1 decibel per wavelength.

The pulse shapes changed only slowly with distance and would not allow the residual attenuation to depend on frequency to any power higher than about one.

The very near surface had a pronounced and chaotic effect on the recorded amplitudes, so making it necessary to make large numbers of observations in order to obtain reliable attenuation factors.

The multiply reflected refraction guided between the free surface and the shallow refractor was observed for distances ranging from 5,000 to 30,000 feet. At the mean distance of 15,000 feet its amplitude was about 60 times that expected for the head wave pulse.

C. B. Officer : The Refraction Arrival in Water-Covered Areas, *Geophysics,* Vol. 18, pp. 805-820, 1953.

The material presented in this lecture is published as follows :

1) The Variation with Distance of the Amplitude of Critically Refracted Waves, *Geophysical Prospecting,* Vol. V, pp. 300-316. 8 Figs, The Hague, September, 1957.

2) Multiply Reflected Refraction in a Shallow Layer, *Geophysical Prospecting,* Vol. V, December, 1957.

Dr. Blake : What was the thickness of the refracting layer at shallow depth, relative to wave length ?

Dr. O'Brien : About one-half wave length.

135. — The paper by *Z. Droste,* An Angular Distribution of Energy Density Emitted from a Seismic Focus, is read in title only.

The aim of this paper is to find the distribution of the energy density by taking into account the conditions given in the focus. These conditions are determined by the type of the distribution of forces in the focus depending on time. Formulas are derived which give the flow of the energy through the surface of a sphere in a unit time and which take the type of the source into account.

The complete text has been published in *Acta Geophysica Polonica,* Vol. IV, No. 4, pp. 215-225, 3 Figs, Warsaw, 1956.

136. — The paper by *R. Teisseyre,* An Outline of the Theory of Non-local Seismic Foci, is also read in title only.

This paper discusses the phenomenological theory of the seismic foci. The point models of Keilis-Borok represent the first approximation for general models. — The simple extension to non-local models can be effected by means of the functions $\delta(\varkappa, \alpha)$, which, in the limit, become the Dirac function $\delta(\varkappa)$ (a point model). The non-local character of the focus depends on the parameter α. — The proposed method of interpretation is based primarily on the ordinary dynamical determinations for point model of the focus. Then, for the case in question, the differences between the theoretical and experimental data can be interpreted by means of a non-local characteristic for the focus.

The complete text has been published in *Acta Geophysica Polonica,* Vol. IV, No. 4, pp. 226-236. 3 Figs, Warsaw, 1956.

137. — *Dr. Sherwood* presents his paper on The Displacement Field in a Stratified Solid Medium Due to Localized Impulsive Forces.

La méthode d'analyse ci-dessous s'applique à divers types de force impulsive agissant soit en un point (cas à trois dimensions), soit sur une ligne parallèle aux interfaces des couches (cas à deux dimensions). L'équation vectorielle hétérogène de mouvement de la région située aux abords immédiats d'une force particulière est résolue en premier lieu par les méthodes courantes de transformation intégrale. Cela donne des déplacements ayant des parties constituantes parallèles et perpendiculaires aux interfaces, sous forme de superpositions intégrales d'une dilatation de plan (P) allant vers l'extérieur et d'ondes de rotation (S).

Chaque onde de plan relève d'une interface adjacente et en général elle produit quatre ondes nouvelles qui ne sont que la réflexion et la transmission des ondes P et S. Il s'ensuit un processus en cascade qui, en fin de compte, résulte en une infinité d'ondes dans chaque couche. L'onde première étant une onde de superposition intégrale chaque membre de l'infinité d'ondes est une partie constituante d'une superposition intégrale semblable. Il est donc évident que toute composante de déplacement en n'importe quel point est déterminée par la somme infinie des superpositions intégrales d'ondes. On peut évaluer chaque terme de la somme. Tout commence par une discontinuité à un moment déterminé, suivie d'une perturbation prolongée. Il est donc possible d'obtenir un déplacement d'une durée voulue en évaluant un nombre fini des termes. Cette technique, cependant est peu commode loin de la source, où de nombreux termes commencent à contribuer au déplacement en un court incrément de temps. Dans ce cas les termes sont additionnés sous leur forme analytique, et l'on réalise l'évaluation finale au moyen de méthodes d'intégration approchées.

On a appliqué cette méthode d'analyse au cas simple d'une force impulsive normale agissant sur une ligne à la surface d'une plaque élastique homogène et isotrope. Les valeurs calculées des déplacements correspondent aux observations expérimentales.

The complete text will be published under the title Elastic Wave Propagation in a Semi-infinite Solid Medium, *The Proceedings of the Physical Society,* Section B, probably in March, 1958.

Prof. Press asks if the problem studied is two- or three-dimensional.

Dr. Sherwood : The theoretical analysis was performed for a line source in a three-dimensional medium, but the symmetry was such that it could be considered as a two-dimensional problem.

Dr. Danes : Does not the « thickening » of the sheet model, due to the Poisson's ratio of the material, make the results different from those, when the third dimension is infinite ?

Dr. Sherwood : The velocity is different, but the geometry is the same. The equivalence between the case of a line source in a three-dimensional medium and the analogous problem of a point source in a two-dimensional sheet was established by J. Oliver, F. Press, and M. Ewing : Two-dimensional Model Seismology, *Geophysics,* Vol. 19, No. 2, pp. 202-219, 11 Figs, April, 1954.

Father Ingram : I think that this work, as that of Dr. Press, is most important. I would like to ask if phase changes were observed in the recordings of PP at the surface. What was Poisson's ratio for the material used ?

Dr. Sherwood : The computations were made assuming an effective Poisson's ratio of 0.25, that is a ratio of $\sqrt{3}$ between the P and S wave velocities.

Dr. Lapwood : I congratulate Dr. Sherwood on a very elegant piece of mathematics, and especially on presenting together his mathematical and experimental results, showing excellent agreement. — May I ask one or two questions about method ? You gave a geometrical construction for the terms arising by repeated reflection and refraction of P and S plane waves. Did you in fact construct your expressions in this way or by solution of the wave equation with appropriate boundary conditions ?

Dr. Sherwood : By geometrical construction.

Dr. Lapwood : I agree that this is by far the best way. Dr. S. D. Chopra working recently in Cambridge on the problem of a source in a low-velocity layer, also saw that this method could be applied to any multilayered medium. It is very remarkable that the full solution, including head waves and interface or surface waves, can be derived although in the first place only simple ray-paths are considered. Since the solution of a large system of boundary condition equations is sidetracked and the shape of any pulse can be obtained separately for any point, the method should greatly facilitate comparison of theory and observations. — I have the impression that in this method the velocities of surface and interface waves are not given directly : the Rayleigh wave at distance, for instance, is given by superposition, as in Pekeris' problem, of a large number of terms which are separately evaluated. Do you see any way of deriving single expressions for Rayleigh, Love, and Stoneley waves and also of obtaining their velocities ? In other treatments the expression giving velocities is lost during the Bromwich expansion which is equivalent to your method.

Dr. Sherwood : I thank Dr. Lapwood for his very kind remarks. The transmitted and reflected waves at a plane boundary due to an incident plane wave will have amplitude coefficients possessing denominators which are zero when interface waves, such as Stoneley and Rayleigh waves, are created. Thus solutions of the equation formed by equating the denominator of the reflection or transmission coefficients to zero will give the velocities and complex angles of propagation of these waves. However, one does not obtain a single displacement expression for such a wave and the disturbance around its epoch time must be obtained by summing the relevant dilatation and rotation displacements in this region.

The session is closed.

MEETING OF THE COMMITTEE FOR THE INTERNATIONAL GEOPHYSICAL YEAR

FRIDAY, SEPTEMBER 13 (morning)

The session is opened at 11.05 a.m. with *Prof. Beloussov* as chairman.

The following persons attend the session : Miss Lehmann, Mme Kondorskaya, Prof. Beloussov, Dr. Båth, Mr. Ben Osman, Dr. De Bremaecker, Prof. Bullen, Prof. Byerly, Prof. Egyed, Dr. Ergin, Dr. Hodgson, Rev. Dr. Ingram, Mr. Paes Clemente, Rev. Dr. Romañá, Prof. Rothé, Dr. Satô, and Dr. Stoneley.

Prof. Beloussov says in introduction that Egypt, Vietnam, Greece have joined the I.G.Y. seismic program, that the total number of participating stations is about 310, but that the list of stations is still incomplete, and furthermore that a manual has been prepared, which will be published very shortly. A regional conference in W. Pacific organized a center for the area of the W. Pacific. He further suggests the following points for discussion :

1) Exchange of data for Arctic and Antarctic earthquakes.
2) Form of presentation of measurements for magnitude determination.
3) Travel time curves for Arctic and Antarctic.
4) Publication in the Annals of the I.G.Y.
5) Possibly : program for the investigation of the structure of the earth.

The suggested agenda are accepted and no other proposals put forward.

1) *Prof. Beloussov* explains that the Soviet scientists proposed to organize an exchange of data for the Arctic more rapidly than usual. The mutual exchange was proposed for Arctic shocks at first, e. g. by letters to be sent every 10 days. — In reply to questions from a number of participants in the session, *Prof. Beloussov* explains his proposal further : The letters are to be sent to the central stations interested, in addition to the three W.D.C. Only earthquakes which occur in the Arctic or in the Antarctic are included in the proposal. — It is objected that some stations in the Arctic, for instance, have communication only by telegram and that some of them are operated by unskilled personnel. Furthermore, that it is frequently difficult or impossible to know the epicenter location only from a reading at a single station.

It is agreed which stations are interested in Arctic and Antarctic shocks resp. and the Secretary General, *Prof. Rothé,* is asked to write a circular to these different central stations, asking them to exchange their data by sending, every 10 days if possible, special bulletins concerning all earthquakes occurring in the Arctic and in the Antarctic resp. The following list of stations is copied from this circular, dated October 15, 1957.

A) Earthquakes occurring in the Arctic :

CANADA	Dominion Observatory Seismological Division OTTAWA
DENMARK	Geodetic Institute Seismisk Afdeling Nr. Farimagsgade 1 COPENHAGEN K
FINLAND	Seisminen Asema Fysiikan Laitos Siltavuorenpenger 20 HELSINKI
ICELAND	Seismological Station Vedurstofan REYKJAVIK
JAPAN	Japan Meteorological Agency Ote-Machi, Chiyoda-Ku TOKYO
NORWAY	Jordskjelvstasjonen Universitetet i Bergen BERGEN
SWEDEN	Dr. Markus Båth Meteorological Institute UPPSALA
USA	U.S. Coast and Geodetic Survey Seismological Department WASHINGTON 25, D. C.
USSR	Central Seismological Station «Moscow» Pyjevsky pereoulok 3 MOSCOW B-17

B) Earthquakes occurring in the Antarctic :

ARGENTINE	Ingénieur S. Gershanik Jefe del Departamento seismologico Observatorio astronomico Universidad Nacional LA PLATA
AUSTRALIA	The Director Riverview College Observatory RIVERVIEW, N.S.W. Sydney
CHILE	Instituto sismologico Universidad de Chile Casilla 2777 SANTIAGO DE CHILE

FRANCE	Institut de Physique du Globe 38. boulevard d'Anvers STRASBOURG
JAPAN	Japan Meteorological Agency Ote-Machi, Chiyoda-Ku TOKYO
NEW ZEALAND	The Director Dominion Observatory P. O. Box 2903 WELLINGTON W. 1
SOUTH AFRICA	Bernard Price Institute of Geophysical Research University of Witwatersrand JOHANNESBURG
UNITED KINGDOM	Dr. R. STONELEY Department of Geodesy and Geophysics Madingley Rise Madingley Road CAMBRIDGE
USA	U.S. Coast and Geodetic Survey Seismological Department WASHINGTON 25, D.C.
USSR	Central Seismological Station «Moscow» Pyjevsky pereoulok 3 MOSCOW B-17

The following persons participated in the discussion of point 1: *Miss Lehmann, Prof. Byerly, Dr. Hodgson, Dr. Stoneley, Mme Kondorskaya, Dr. Båth, Prof. Rothé.*

2) There is a lively exchange of ideas on how much data should be given, regarding amplitudes and periods of body waves and amplitudes of surface waves, for the use in magnitude determinations.

Mme Kondorskaya proposes to use the surface waves, and says that for body waves it is necessary to give the characteristics of the instrument. She also insists upon measuring the very first swing in the case of body wave amplitudes.

Dr. Båth prefers the use of body waves before surface waves, because of the depth dependence of surface waves. He explains that in his bulletins amplitudes and periods are given regularly of P, PP, S, and the various core waves, in addition to surface waves. The amplitudes for the body waves are, in agreement with the procedure adopted in Pasadena, measured in the wave group, which may mean up to about 10 sec after the first onset. For those stations which feel overloaded with work he suggests cutting down the number of phases (identified or unidentified) which are frequently given in the bulletins, and to concentrate on just that information which is necessary for computation of location, depth, and magnitude of the earthquakes. In addition, special features of interest may be remarked.

Prof. Beloussov, Prof. Rothé, Dr. De Bremaecker, Prof. Byerly, Prof. Egyed, Dr. Hodgson, Father Ingram also take part in the discussion by brief remarks or questions.

The importance of giving both body and surface waves for use in the magnitude determination is finally emphasized.

3) *Prof. Byerly :* The difference between the Gutenberg-Richter and the Jeffreys-Bullen travel time curves is small, and perhaps we should not decide between these two.

Prof. Bullen : I think that we should agree on a simple standard to facilitate the interpretation.

The meeting concludes that further research will be needed on this subject.

4) *Prof. Beloussov* refers to the special publication of the I.G.Y. (Annals of the I.G.Y.). He says that this publication should contain general analysis of the seismicity of the Arctic, Antarctic, and the equatorial zones. This could probably be arranged in detail at the Moscow conference of C.S.A.G.I. in August, 1958.

The meeting agrees that national committees and individuals should send their recommendations regarding this publication to Prof. Rothé.

5) Various participants give information on recent developments.

Prof. Byerly : Drs Tuve and Tatel have been sent by the U.S. to South America for crustal exploration. Prof. Byerly also refers to other similar work in U.S.

Dr. Hodgson : Canada will make a large explosion near Ripple Rock next April.

Dr. De Bremaecker gives information on the existing stations in Belgian Congo, and points out that Rhodesia and Nyassaland are going ahead with their program, but that British East Africa is not doing anything yet.

Prof. Beloussov : Soviet seismologists are investigating the shelf in E. Asia ; preliminary investigations are made in the Caspian Sea.

The session is closed.

TWENTY-FIRST SESSION

FRIDAY, SEPTEMBER 13 (afternoon)

Program

10. — Election of Bureau, Executive Committee, and the Committee for the Physics of the Earth's Interior.
11. — Report of the Finance Committee.
12. — Discussion of resolutions.
13. — Seismological dictionary.
14. — Symposia.

The session is opened at 03.00 p.m. with the President, *Prof. Bullen,* in the chair.

10. Election of Bureau, Executive Committee, and the Committee for the Physics of the Earth's Interior

The Assembly unanimously elects *Sir Harold Jeffreys* as President of the Association, and *Dr. Hodgson* and *Dr. Riznichenko* as Vice Presidents.

Prof. Benioff reads the report by the Committee consisting of *Prof. Benioff, Dr. Keilis-Borok,* and *Dr. De Bremaecker* (see point 4, First Session), proposing that *Prof. Rothé* remains as Secretary General of the Association, and that *Dr. Båth* will assist him, having the title of Associate Secretary General (Secrétaire Général Associé). The proposal is unanimously adopted by the Assembly.

The following persons are unanimously elected as members of the Executive Committee : *Prof. Bullen, Miss Lehmann, Prof. Pekeris, Dr. Ritsema,* and *Dr. Vesanen.*

The Committee for the Physics of the Earth's Interior is partially renewed with the following elections of rapporteurs :

Tectonophysics : *Prof. Beloussov, Prof. Vening-Meinesz.*

Gravimetry : *Prof. Goguel.*

Geochronology, Radioactivity, and Geothermy : *Sir Edward Bullard, Prof. Wilson.*

Elasticity and Plasticity : *Sir Harold Jeffreys, Dr. Stoneley.*

11. Report of the Finance Committee

Prof. Gutenberg declares on behalf of the Finance Committee (*Prof. Byerly, Prof. Gutenberg,* and *Dr. Hodgson ;* see point 3, First Session) that the accounts of the Association have been examined and no objection found. He proposes that the accounts be approved.

12. Discussion of resolutions

The finally adopted texts of the various resolutions are given in Appendix 1 both in French and English. Note that the resolutions 1—4 were transmitted to the Union for adoption, whereas the resolutions 5—7 concern only the Association and were not transmitted to the Union.

Resolution 1. The Association approves the resolution presented by the Committee for the I.S.S.

Resolution 2. This resolution was adopted already during the Thirteenth Session, jointly with the Association of Geodesy on Tuesday, September 10, in the afternoon.

Resolutions 3 and 4. These resolutions are jointly presented by our Association and the Association of Physical Oceanography. There is a long discussion of these proposals, before the final wording is adopted by the Association.

Sir Edward Bullard : I think that the idea behind the resolution is that we know the Mohorovičić discontinuity to be much shallower beneath the oceans than it is beneath the continents. We have little evidence as to the depth of the Mohorovičić discontinuity beneath oceanic islands, but it is quite likely that places can be found where it is at an accessible depth.

Prof. Press : Under oceanic islands the layering in the crust is abnormal. Therefore, if one succeeds in drilling to the Mohorovičić discontinuity, the result is not applicable to other regions. Prof. Press therefore questions the advisability of this resolution.

Prof. Dix agrees and says : Is a possible drilling location known ? If so would the cost be $ 10 to 20 million or perhaps much more ? Is this the best way to spend this sum even if it were available ?

Sir Edward Bullard : The resolution may be improved by suggesting investigations if such a drilling is possible.

Prof. Rothé draws attention to the fact that there are two resolutions, one concerning the deep structure (Resolution 3), the other concerning only the sediments (Resolution 4). He further asks if the basalt has not been reached in drilling operations in the U.S.A.

Dr. Carder replies that the basalt was reached during two drilling operations, at depths of 4200—4500 feet.

Prof. Slichter points out that results of enormous importance may be obtained, comparable with the results of artificial earthquakes.

Dr. Blake says he suggested the two resolutions to be combined. The committee suggesting these resolutions considered such a combination undesirable, because the drilling concerned in Resolution 4 is immediately possible, whereas it is not possible to say when one can reach the Mohorovičić discontinuity in this way.

Sir Edward Bullard : The techniques for the two drilling operations is very different. For the deep drilling it will be necessary to drill in hard rock, which is possible. It will be necessary to use the technique of mining drilling and not that of oil drilling.

The modified wording of Resolutions 3 and 4, given in Appendix 1, is adopted by the Assembly.

Resolutions 5—7 are adopted by the Assembly without discussion.

13. Seismological dictionary

Mme Labrouste has kindly given the following report on this point.

Mme Labrouste présente le rapport préparé par le Président, *M. E. Guyot,* qui n'a pas pu venir à Toronto.

« Rappelons que la commission du dictionnaire, désignée par l'Association lors de l'Assemblée Générale de Bruxelles en 1951, comprend trois membres : Madame H. Labrouste de Paris, Monsieur C. F. Richter de Pasadena et le soussigné. M. Richter, probablement trop occupé, n'ayant plus donné signe de vie, la commission s'est pratiquement trouvée réduite à deux membres.

Depuis la réunion de Rome en 1954, nous avons discuté avec Madame Labrouste au cours de trois entrevues qui ont eu lieu à Paris en 1956 et nous avons eu une entrevue avec M. J. E. Holmström de l'UNESCO, chargé de la question des dictionnaires. Ce dernier, auquel nous avons montré le travail déjà fait, nous a conseillé de donner des définitions plus concises, attendu qu'un dictionnaire séismologique ne doit pas avoir l'ampleur d'un traité complet de séismologie dans lequel les matières seraient classées par ordre alphabétique.

Le premier projet que nous avions mis sur pied seul était évidemment très incomplet, en particulier en ce qui concerne les séismographes. Grâce au grand dévouement de Madame Labrouste qui a bien voulu, malgré des occupations très absorbantes, refaire toute la partie instrumentale, celle-ci est au point : Principes et descriptions des différents instruments, constantes, étalonnage, etc. Ces derniers temps, nous avons entrepris la définition des microséismes, y compris les différentes explications que l'on en donne. Nous remercions à ce sujet les collègues qui ont eu l'amabilité de nous envoyer les publications manquant dans notre bibliothèque.

Quant à l'avenir, il faut prendre des dispositions pour que le travail puisse se faire jusqu'au bout, car ce dictionnaire rendrait certainement de grands services. Ayant renoncé à nos fonctions très absorbantes de directeur de l'Observatoire de Neuchâtel, tout en conservant notre chaire à l'Université, nous disposons maintenant de plus de temps qu'autrefois et sommes d'accord de faire un gros effort pour arriver au but. Cependant, nos moyens personnels sont limités, tout d'abord parce que si nous nous sommes occupés du dépouillement des séismogrammes pendant 20 ans à l'Observatoire de Neuchâtel, ce n'était qu'une partie de notre activité et non notre spécialité ; ensuite, parce que notre bibliothèque séismologique est très incomplète. Si tous les instituts séismologiques voulaient bien nous envoyer leurs publications, ils nous rendraient un grand service.

Pour seconder la commission, il faudrait que deux ou trois séismologues se chargeassent de rédiger les définitions du domaine dans lequel ils sont spécialisés. Il s'agirait, en particulier, de la théorie des ondes, des phases d'un séismogramme, détermination des épicentres, durées de propagation, macroséismes, phénomènes accompagnant les tremblements de terre, séismicité, classification des tremblements de terre, échelle d'intensité, magnitude, surfaces de discontinuité à l'intérieur de la terre, cause des tremblements de terre, etc. Nous nous chargerions de réunir tous ces documents et de mettre au point la rédaction définitive. Nous mettrions à la disposition de ces collaborateurs bénévoles notre premier projet dont ils pourraient compléter ou modifier les définitions à leur guise. Nous espérons que deux ou trois collègues voudront bien s'offrir pour cette collaboration.

Une question se pose encore, concernant les termes qui étaient utilisés autrefois et qu'on n'emploie plus maintenant. Faut-il les mentionner dans le dictionnaire (avec réserves) ou les laisser tomber complètement? Leur maintien pourrait peut-être rendre service à ceux qui, lisant d'anciens ouvrages, ignorent la signification de certains termes utilisés par les auteurs.

En terminant, nous tenons à remercier très vivement Madame H. Labrouste qui, malgré ses nombreuses occupations, a fait un gros effort pour mettre au point toute la question instrumentale. »

Neuchâtel, le 9 août 1957.

Le président de la commission du dictionnaire :

Edmond GUYOT
Professeur à la Faculté des Sciences
Rue de la Maladière 27
Neuchâtel (Suisse)

Répondant à une demande d'explication de *M. De Bremaecker, Mme H. Labrouste* indique qu'à son avis la préparation du dictionnaire doit comporter un choix parmi les termes et les symboles dont l'adoption sera soumise à l'Assemblée Générale, les termes tombés en désuétude devant être éliminés. Une discussion s'engage sur la traduction des termes qui, le moment venu, devra également faire l'objet de décisions.

Conformément au vœu exprimé par le Président, *Mme H. Labrouste* sollicite la collaboration de quelques Séismologues pour préparer ou revoir des définitions dans le domaine où ils sont spécialisés.

Les personnalités suivantes acceptent d'apporter leur collaboration à la Commission :

Prof. Gutenberg	(Séismicité et Energie)
Prof. Bullen	(Théorie des Ondes)
Mlle Lehmann	(Durées de propagation)
Dr. Benioff	(Appareils)
Dr. Press	(Agitation)

Il est demandé à *Mme H. Labrouste* d'assurer les liaisons entre la Commission et les collaborateurs.

14. Symposia

The Russian delegation proposes a symposium on experimental tectonics, modelling, theory.

Prof. Bullen expresses his thanks to all those who have actively contributed to making this Assembly a very successful one. He finally declares the General Assembly for our Association closed.

Note. It is a great pleasure for me to acknowledge every assistance received in the preparation of this volume ; first of all, my thanks go to the Secretary General of our Association, Prof. J. P. Rothé, whose experienced advice has been indispensable in this work ; furthermore, to those who kindly made their notes during the sessions available to me ; finally, to all those who have answered my letters and in this way given valuable information which has been included in this volume.

M. Båth.

ANNEXE I

RESOLUTIONS

Adopted by the Toronto Assembly
(1957)

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

RESOLUTIONS (texte français)

Note : Les résolutions 1—4 sont transmises pour adoption par l'Union, tandis que les résolutions 5—7 ne sont pas transmises à l'Union.

RESOLUTION 1.

L'Association de Séismologie et de Physique de l'Intérieur de la Terre voit avec inquiétude décroître les allocations qui sont annuellement accordées par l'I.C.S.U. pour le travail de l'International Seismological Summary.

Cette diminution rend impossible de combler le retard dans la publication, ce qui constitue actuellement l'un des problèmes les plus urgents de l'I.S.S.

Si l'I.S.S. ne peut rattraper son retard le Trésor Britannique serait amené à supprimer sa subvention, auquel cas tout travail devrait cesser. L'Association désire affirmer qu'il est d'importance capitale pour les études concernant l'Intérieur de la Terre que le travail de l'I.S.S. soit poursuivi d'une manière adequate ; dans ce but et pour tenir compte de l'augmentation du prix de la publication en correlation de l'augmentation du nombre des stations l'Association demande qu'une subvention d'au moins de $ 10,000 soit accordée annuellement par l'I.C.S.U.

RESOLUTION 2.

1. Un système uniforme de cartes d'anomalies de Bouguer à l'échelle de I M, les anomalies étant calculées sur la base d'une densité de 2 67 g/cm^3 (pour les corrections topographiques) doit être préparé dans chaque pays.

Il doit être possible et désirable d'utiliser ces cartes en comparaison avec des cartes des différents types de corrections isostatiques à la même échelle.

Des cartes plus détaillées à plus grande échelle doivent montrer les anomalies de Bouguer calculées avec la meilleure valeur possible de la densité (pour les corrections topographiques) les valeurs utilisées ayant été contrôlées. Si cependant on désire utiliser une densité standard la valeur choisie doit être 2.67 g/cm^3.

2. Les observations de base et les calculs demandés pour l'utilisation des mesures gravimétriques aux problèmes géophysiques doivent être entrepris dans chaque contrée et comprendre le calcul de la correction topographique (Geländereduktion). Ce calcul doit être de préférence poussé jusqu'à un rayon de 167 km ou au moins de 28.8 km.

RESOLUTION 3.

Comme la composition du manteau de la terre sous la surface de discontinuité de Mohorovičić est un des problèmes les plus importants et non encore résolu de la géophysique,

comme, bien que les observations séismiques, gravimétriques et magnétiques aient déjà donné des indications significatives sur la nature du matériel du manteau, il est désirable cependant que soient recueillis des échantillons qui puissent être examinés aux points de vue pétrographique, physique et chimique,

comme les rapides progrès de techniques modernes de forages profonds permettent d'envisager la possibilité de forer un puits de 10 à 15 km de profondeur à partir d'une île océanique

et comme l'étude du matériel crustal au-dessus de la discontinuité de Mohorovičić est aussi d'un grand intérêt

il est recommandé que l'Union Internationale de Géodésie et de Géophysique invite les nations du Globe et spécialement celles où les techniques de forages sont très développées, à étudier la possibilité et le prix d'une opération de forage jusqu'à la surface de discontinuité de Mohorovičić en un endroit où cette discontinuité se rapproche de la surface.

RESOLUTION 4.

Les recherches séismiques ayant montré que les sédiments sous les océans sont particulièrement minces et comme il paraît possible que des techniques puissent être mises au point pour forer au travers de ces couches et pour examiner la nature des sédiments et des roches crustales sous-jacentes, il est recommandé que l'Union Internationale de Géodésie et de Géophysique appuie activement le développement des techniques de forages et leur large utilisation en mer.

RESOLUTION 5.

L'A.I.S.P.I.E. fait remarquer que la séismicité du Graben de l'Afrique Orientale est particulièrement mal connue et que des renseignements précis sont désirables sur cette région et recommande qu'un effort spécial soit fait à l'occasion de l'A.G.I. pour équiper le Kenya, l'Uganda et le Territoire du Tanganyika de stations séismographiques modernes et demande aux pays voisins ayant des connaissances spéciales en ce domaine de fournir toute l'aide possible pour la réalisation de ce projet.

RESOLUTION 6.

Il est désirable que si possible les stations séismologiques puissent envoyer leurs données à l'I.S.S. sous forme de cartes du format de $4\frac{1}{2} \times 3$ pouces ($11{,}5 \times 7{,}5$ cm), chaque carte contenant les lectures pour une seule station et pour un jour ou pour une seule station par séisme. Les stations qui ont beaucoup de données rendraient service en envoyant à l'I.S.S. leurs bulletins en 3 exemplaires.

RESOLUTION 7.

Reconnaissant la grande valeur des cartes de déterminations préliminaires d'épicentres qui sont très rapidement établies et diffusées par le service séismologique de l'U.S.C.G.S., l'Association Internationale de Séismologie et de Physique de l'Intérieur de la Terre exprime sa vive gratitude au « Coast and Geodetic Survey, Washington ».

INTERNATIONAL ASSOCIATION OF SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR

RESOLUTIONS (English Text)

Note : The resolutions 1—4 are transmitted for adoption by the Union, whereas the resolutions 5—7 are not transmitted to the Union.

RESOLUTION 1.

The International Association of Seismology and Physics of the Earth's Interior views with alarm the decreasing allocation from the I.C.S.U. grant to finance the International Seismological Summary.

This reduction will make it impossible to continue to overtake the arrears of publication, which is at present one of the pressing problems of the I.S.S. If the I.S.S. should again fall into arrears the British Treasury is likely to discontinue its subvention, in which case the work would cease altogether. The Association wishes to assert the vital importance to studies of the Earth's interior of continuing this task in an adequate manner ; for this purpose, and to deal with the increase in the number of stations at the cost of publication a subvention of at least $ 10.000 is required annually from the I.C.S.U.

RESOLUTION 2.

1. A uniform system of maps of Bouguer anomalies on the scale of I M, with the anomalies calculated on the basis of the density being 2.67 g/cm³ (for the topographic corrections), should be prepared within each country.

It will be possible and desirable to use these maps in association with maps of different types of isostatic corrections on the same scale.

More detailed maps on larger scales should show the Bouguer anomalies computed with the best available value of the density (for the topographic corrections), the values used being stated ; if however, it is desired to use a standard density, the value should be 2.67 g/cm³.

2. The basic observations and computations required for the application of gravity measurement to geophysical studies should be

carried out within each country and should be carried as far as the calculation of the topographic correction (Geländereduktion). This calculation should preferably be extended to 167 km or at least to 28.8 km radius.

RESOLUTION 3.

Whereas the composition of the Earth's mantle below the Mohorovičić discontinuity is one of the most important unsolved problems of geophysics,

and whereas, although seismic, gravity and magnetic observations have given significant indications of the nature of this material, actual samples that could be examined petrographically, physically and chemically are essential,

and whereas modern techniques of drilling deep wells are rapidly developing to the point where drilling a hole 10 to 15 km deep on an oceanic island may be feasible,

and whereas the crustal material above the Mohorovičić discontunity is also of prime interest, therefore be it

Recommended that the International Union of Geodesy and Geophysics strongly urges the nations of the World and especially those experienced in deep drilling to study the feasibility and cost of an attempt to drill to the Mohorovičić discontinuity at a place where it approaches the surface.

RESOLUTION 4.

Whereas it has been shown by seismic work that sediments in the deep ocean are unexpectedly thin and whereas it seems possible that techniques could be developed to drill through them and to examine the nature of the sediments and of the subjacent crustal rock, it is recommended that the International Union of Geodesy and Geophysics support the vigorous development of techniques of drilling through the sediments and their widespread use at sea.

RESOLUTION 5.

The I.A.S.P.E.I. draws the attention to the fact that the seismicity of the East African Rift Valley is particularly poorly known and that precise information on this region is desirable and

Recommends that a special effort be made on the occasion of the I.G.Y. to equip Kenya, Uganda and the Tanganyika Territory with modern seismographic stations and

Asks the neighbouring countries having special knowledge in this matter to give all possible assistance for the realization of this project.

RESOLUTION 6.

It is desirable that wherever possible the observing stations should supply their data to the I.S.S. in the form of cards, size 4 ½×3 inches

(11,5×7,5 cm), each card containing the readings for a single station for one day, or for a single station per earthquake. Stations which have much data could help by sending in three copies of their bulletins.

RESOLUTION 7.

Considering the great value of the cards with preliminary determination of epicenters which are very rapidly made up and sent out by the seismological service of the U.S.C.G.S., the International Association of Seismology and Physics of the Earth's Interior expresses its lively gratitude to the Coast and Geodetic Survey, Washington.

ANNEXE II

LIST OF NATIONAL COMMITTEES

and of Persons Working in Seismology and Physics of the Earth's Interior

LIST OF NATIONAL COMMITTEES AND OF PERSONS WORKING IN SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR

On November 15, 1957, the Associate Secretary General of the Association of Seismology and Physics of the Earth's Interior, sent out a circular to 76 different countries, asking for the following information :

A : Member organisation of the International Union of Geodesy and Geophysics (complete address of president or secretary of national committee, if such a committee exists).

B¹: National Committee for Geodesy and Geophysics.

B²: National Committee for Seismology and Physics of the Earth's Interior.

C : Persons representing your country in the Association of Seismology and Physics of the Earth's Interior (information wanted also from non-member countries).

D : Other persons working in seismology, whose names have not appeared above (information wanted also for countries with no national committee).

E : Other persons working in the field of physics of the earth's interior, whose names have not appeared above. It is necessary to specify here the field of research for each person : thermal properties of the earth, radioactivity, geochronology, tectonophysics, gravity anomalies etc with relation to seismological problems, laboratory investigations of seismological application etc (information wanted also for countries with no national committee).

It is a great pleasure for the Associate Secretary General to acknowledge at this place all the replies which have been obtained from various countries, and which have been extremely helpful in making the following list up-to-date. For those countries which have not sent in replies, information has been obtained from various sources, as the Comptes Rendus No. 9, pp. 77-90, and No. 10, pp. 131-142, the I.U.G.G. News Letter, and the I.U.G.G. Chronicle. It is requested that the following list be examined by the respective countries and the Associate Secretary General of our Association be informed about every information below which is erroneous, incomplete, or out-of-date.

ARGENTINE

A : Comité Nacional de la Unión Geodesica y Geofisica Internacional, Cabildo 381, Buenos Aires.

B¹: General V. H. J. Hosking, Presidente del Comité Nacional de la U.G.G.I., Cabildo 381, Buenos Aires.

D : Ing. S. Gershanik, Jefe del Departamento de Geofisica, Instituto Superior del Observatorio, Paseo El Bosque, La Plata.

Agr. Pastor J. Sierra, Instituto Superior del Observatorio, Paseo El Bosque, La Plata.

Enrique U. Jaschek, Instituto Superior del Observatorio, Paseo El Bosque, La Plata.

Dr. M. S. Cappelletti, Servicio Meteorológico Nacional, Paseo Colón 317, Buenos Aires.

Dr. D. Valenzuela, Servicio Meteorológico Nacional, Paseo Colón 317, Buenos Aires.

Ing. F. Vila, Laboratorio de Yacimientos Petrolíferos Fiscales, Florencio Varela, Provincia de Buenos Aires.

Sr. R. C. Roldán, Servicio Meteorológico Nacional. Paseo Colón 317, Buenos Aires.

Sr. B. Arrambido, Observatorio Regional, Parque General San Martín, Mendoza.

Ing. F. Volponi, Facultad de Ingeniería de San Juan, San Juan.

AUSTRALIA

A : The Secretary, Australian Academy of Science, G.P.O. Box 6, Canberra, A.C.T.

B¹: Prof. K. E. Bullen, Department of Applied Mathematics, University of Sydney, Sydney, N.S.W.

Dr. D. F. Martyn, C.S.I.R.O. Radio Research Laboratories, Field Station, Werombi Road, Camden, N.S.W.

Dr. C. H. B. Priestley, C.S.I.R.O. Meteorological Physics Section, Station Street, Aspendale, Victoria.

Mr. J. M. Rayner (Convenor-Secretary), Deputy Director, Bureau of Mineral Resources, Geology & Geophysics, Dept. of National Development, P.O. Box 378, Canberra, A.C.T.

Mr. R. F. Thyer, Chief Geophysicist, Bureau of Mineral Resources, Geology & Geophysics, 203 Collins Street, Melbourne, Victoria.

Dr. F. W. G. White, Chief Executive Officer, C.S.I.R.O., 314 Albert Street, East Melbourne, Victoria.

Prof. J. C. Jaeger, Department of Geophysics, Australian National University, Canberra, A.C.T.

Prof. E. S. Hills, Department of Geology, University of Melbourne, Melbourne, Victoria.

Mr. B. F. Lambert, Director of National Mapping, National Mapping Division, Acton, Canberra, A.C.T.

B²: Fr. T. N. Burke-Gaffney (Convenor-Secretary), Riverview Observatory, Riverview, Sydney, N.S.W.

Prof. K. E. Bullen, Department of Applied Mathematics, University of Sydney, Sydney, N.S.W.

Dr. O. A. Jones, Department of Geology, University of Queensland, St. Lucia, Brisbane, Queensland.

Mr. R. F. Thyer, Chief Geophysicist, Bureau of Mineral Resources, Geology and Geophysics, 203 Collins Street, Melbourne C 1, Victoria.

C : Prof. K. E. Bullen (Retiring President of the Association of Seismology and Physics of the Earth's Interior, Member of its Executive Committee and of the Committee for the I.S.S.), Department of Applied Mathematics, University of Sydney, Sydney, N.S.W.

D : Dr. B. A. Bolt, Dept. of Applied Mathematics, University of Sydney, Sydney, N.S.W.

Prof. L. G. H. Huxley, Dept. of Physics, University of Adelaide, Adelaide, South Australia.

Mr. D. J. Sutton, Dept. of Physics, University of Adelaide, Adelaide, South Australia.

Prof. W. H. Bryan, Dept. of Geology, University of Queensland, Brisbane, Queensland.

Dr. O.-A. Jones, Dept. of Geology, University of Queensland, Brisbane, Queensland.

Dr. J. P. Webb, Dept. of Geology, University of Queensland, Brisbane, Queensland.

Mr. P. S. Upton, Dept. of Geology, University of Queensland, Brisbane, Queensland.

Mr. H. A. Doyle, Dept. of Geodesy, Australian National University, Canberra, A.C.T.

Mr. H. S. Spigl, The Observatory, Perth, W.A.

Mr. P. F. Rheinberger, Riverview College Observatory, Riverview, N.S.W.

Prof. S. W. Carey, Dept. of Geology, University of Tasmania, Hobart, Tasmania.

Mr. K. Hogan, Snowy Mountains Hydro-Electric Authority, Cooma, N.S.W.

Mr. D. Norris, Snowy Mountains Hydro-Electric Authority, Cooma, N.S.W.

Mr. L. S. Prior, Bureau of Mineral Resources, Geology and Geophysics, 203 Collins Street, Melbourne, Victoria.

Mr. J. C. Dooley, Bureau of Mineral Resources, Geology and Geophysics, 203 Collins Street, Melbourne, Victoria.

Mr. A. F. Tillott, Bureau of Mineral Resources, Geology and Geophysics, 203 Collins Street, Melbourne, Victoria.

Mr. C. A. van der Waal, Bureau of Mineral Resources, Geology and Geophysics, 203 Collins Street, Melbourne, Victoria.

Mr. P. M. McGregor, Magnetic Observatory, Watheroo, W.A.

Mr. J. A. Brooks, c/o Resident Geologist, Port Moresby, Papua.

Mr. A. Taylor, Resident Geologist, Rabaul, New Guinea.

E : Mr. J. C. Dooley, Bureau of Mineral Resources, Geology and Geophysics, 203 Collins Street, Melbourne, Victoria.

Mr. I. B. Everingham, Magnetic Observatory, Watheroo, W. A.

AUSTRIA

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B²: Ein Landeskomitee für Seismologie besteht in der Schweiz nicht. Innerhalb des Schweizerischen Landeskomitees der U.G.G.I. haben sich folgende Herren als interessiert an Seismologie bezeichnet :

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