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Remarques sur le tremblement de terre du Japon du 1^er^ Septembre 1923

(Séisme de Kwanto)

Notes on the nature of the Kwanto Earthquake

Japan, on Sept. 1, 1923

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ABSTRACT

This paper is prepared for the purpose of giving the writer's interpretation of the Phenomena caused by the last great Kwanto earthquake on September 1, 1923.
The most conspicuous change took place along a line running from northwest to southeast across the Sagami Bay. Elevation of the northeast side of this line seems to have been the primary action. The continuous elevation of the land of the Miura Peninsula observed during some ten years before the catastrophe supports this idea. The depression in the southern part of the

bay is considered to have taken place reactionary by the yielding along the zone of maximum stress difference.

There are evidences suggesting the southward, or rather southeastward, displacements of the crust in the disturbed area.

The first shock started somewhere near Kozu and was followed by several others in a few seconds, which occurred probably along the line of most conspicuous changes across the Sagami Bay. Then followed the general panic. The whole motion was characterised by slow movements ; especially noteworthy are the large oscillations of a very long period. These phenomena are considered to be due to the plastic nature of the yielding. The depth at which the first shock occurred is roughly estimated at some thirty kilometers. Knowledges about the strength of the crust and the behaviour of rocks under the pressure prevailing at the said depth seem to support the above consideration. The long period oscillations are probably due to the mass movement of the superficial part of the crust above the plastic layer.

The historical and geological records suggest to us that Kanto has been the seat of repeated earthquakes. The distribution of anomalies of gravity suggests to us relative defect of mass beneath the Kanto district compared to the northwest. The stress from northwest to readjust this inequality might be considered as the principal cause of these catastrophes.

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1. — CHANGE OF THE LITHOSPHERE AT ITS SURFACE

The general disturbance on land caused by the Kwanto earthquake of September 1, 1923, was severest in the region near the northwestern shore of the Sagami Bay and also at the Aluvial plain near the southern end of the Boso Peninsula.

Fig. 1. — Destruction of a Concrete Bridge near Kozu.

Elevation of land was observed along the shore by the water marks on the elevated rocks. So far as it concerned to the shore, the present writer could draw, from his personal observations, parallel lines of equal elevation which ran approximately from northwest to southeast. The line of maximum elevation of about one and a half meter passed from near Oiso to the southern ends of Miura and Boso Peninsulas. This was lately proved to have been generally correct by precise levelling by the Geodetic Department of the Imperial Japanese Army (¹).

Fig. 2. — Uplift of the Land at Jogashima, south end of the Miura Peninsula.

Remarkable changes of the bottom of the Sagami Bay were revealed by soundings by the Hydrographic Office of the Imperial Japanese Navy (²). Putting the minor features aside for a moment, we see that the southern half of the bay increased its depth about one hundred meters in average, while the northern half generally decreased the depth some two hundred meters. (See fig. 4). The boundary line of these two areas run from northwest to southeast for some forty kilometers. The

(¹) Pamphlet published by that department, 1924.
(²) Pamphlet published by that office, 1923.

depressed area was formerly generally flat, slightly more than one thousand meters deep, which could be considered as the continuation of the Pacific Ocean gulfing northwestward into the bay. This deeper part continues to the shallower part in the north through an irregular and rather steep slope. It was along this slope that the most conspicuous elevation took place during that great earthquake. Here we observe many minor patches of deepened and shallowed areas which occurred in such a manner that the former irregularities of the bottom were smoothed out. Still the general feature is that the bottom was shallowed along this zone of steeper slope and deepened in the southern part. The local deepening of three hundred meters to the northwest of the elevated area seems important as it is stated later.

It is noteworthy that such a magnificent change took place only in the sea bottom whereas the land area was affected in a small amount compared to it.

From observations of mean sea level at many tidal stations during the years between 1895 and 1910, Prof. Omori (1) noticed that the land at Aburatsubo in the Miura Peninsula was lowering with the mean rate of 1. 4 cm. per year. This rate decreased in the last few years of the said period, and then this region showed the tendency of rising, which continued up to the last catastrophe (2). This seems important in considering the nature of the original stress of the earthquake to have worked so as to cause the upheaval. Before the California earthquake of 1906, the whole disturbed area was moving northwestward. By the earthquake, however, the east side of the famous fault rebounded back toward the southeast, while the other made one more step in the same direction as before (3). Prof. Reid put stress on this fact

(1) *Publ. Eqke. Inv. Comm.*, Vol. V. N° 2, 1913.

(2) Observed by the Geod. Dept. I. J. A. not yet published.

(3) Report of the State Earthquake Investigation Commission on the California Earthquake of 1906. Carnegie Inst., 1908-10.

and proposed his elastic rebound theory (1). In the present case similar relations seem to hold in the vertical direction at least.

2. — Horizontal Displacement

The only knowledge we have at present about the horizontal displacement in the seismic area is that at Mitaka, 20 km. West of Tokyo, an elongation of 3. 2 mm. in a distance of 100 meters in the north-south direction was disclosed as a result of precise measurement. Mitaka is about 60 km. north of the southern end of the Miura Peninsula. If we can assume that the displacement began 60 km. further north and took place in the same rate, the conclusion will be that the southern end of the peninsula must have moved to the south nearly 4 meters. It is to be added that in the result of the said measurements we can see a slight evidence suggesting relative displacement toward southeast. It was noted above that we had a local area of deepening of 300 meters at the northwest of the area of elevation. This might mean that the elevation was accompanied by southward, or rather southeastward, displacement, in consequence of which either a decrement of pressure in the crust or a sort of crustal opening in large scale might have developed at that position.

The result of triangulation over the seismic area, which is said to be planned by the Landsurvey Department, is expected to disclose very important and interesting results as to the horizontal displacements there.

3. — Direction of Overturning.

Choosing articles of equal ease of overturning in all directions, the present writer observed the directions

(1) M. Yamada, Pamphlet published by the Geodetic Comm. Dept. of Educ., 1923.

of their overturning all over the disturbed area. Among the articles the stone and bronze lanterns, tomb stones and stone gate pillars were the most available. Singular objects such as the collapsed light house at Shirahama, the overturned water tanks at Tateyama station, etc., were also utilised.

Fig. 3. — Overturned Lanterns at Ueno, Tokyo.

These directions are very complicating in the regions near Kozu and Tateyama. But after careful analysis it was found that they could be grouped into three. Eliminating the two groups which seem to be the results of disturbances from two local centers above mentioned, the remaining directions show remarkable regularity in two sets. One of them converges approximately in the Sagami Bay where the maximum upheaval took place. The other occurs, as is shown by the heavier arrows in Fig. 4, generally in the direction of N 50° W in the northern part. This direction gradually turns to the north as we proceed southwards into the two peninsulas and finally approaches to the direction of N 20° SW at the southern ends. In Izu Peninsula and Oshima Island the direction falls generally in N 25° W though the observed cases are not so numerous.

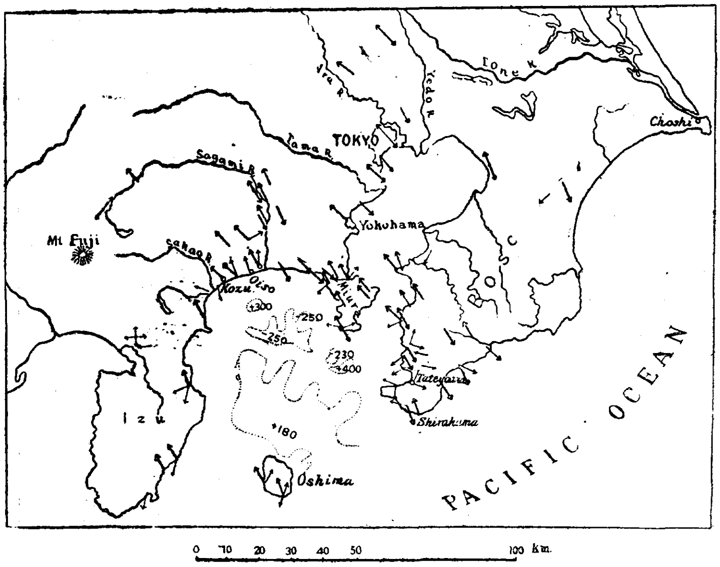

Fig. 4. — Direction of Overturning by the Earthquake

This last set of northwest direction of overturning all over the seismic area seems to the writer to be worth of special attention.

4. — THE STARTING SHOCK.

The seismographs of the Kwanto earthquake at many stations showed that the initial motion was not a simple one, but showed a few steps, as is seen in the Tokyo record, for example, published by Prof. Imamura. (Fig. 6). This fact seems to be of very important meaning, i. e., it suggests that there originated so many separate shocks in the first few seconds.

With the above view the writer examined himself the seismographs at several observatories. Taking the first displacement up to the first step, not the first maximum displacement, the azimuths of the first motion at different stations were measured to be as follows :

Hamamatzu	S 65° W
Nagoya	S 83° W
Gifu	N 86° W
Matsumoto	N 41° W
Nagano	N 30° W
Maebashi	S 3° E
Kumagai	S 23° W
Tokyo	N 42° E
Choshi	S 80° W
Mera	N 45° W

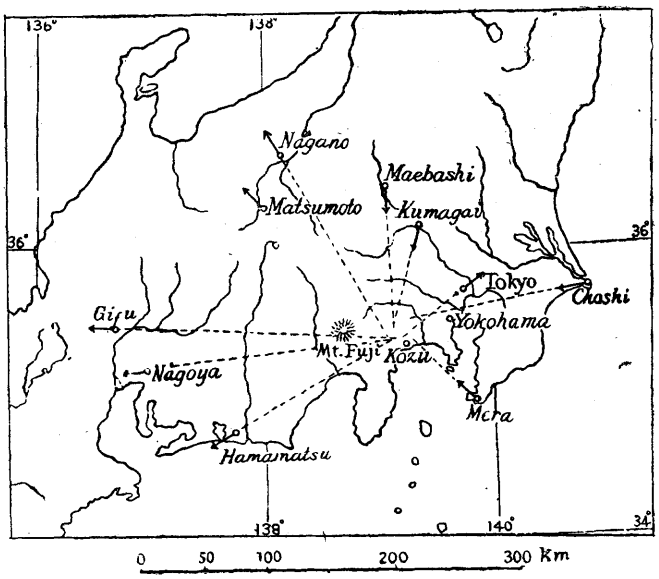

Fig. 5. — The First Motion and the Starting Point of the Shock.

These directions converge pretty well somewhere on the land near Kozu on the northwestern shore of the Sagami Bay. The present writer takes this as the origin in the sense that the destructive movement began from this point at the very beginning.

5. — THE WHOLE CATASTROPHE

It is te be noticed that this origin does not coincide with the largest seismic effect on the surface of the lithosphere, i. e., the central portion of the Sagami Bay. When we observe a fault or other phenomena due to an earthquake, we are looking at the integrated result as it is left after all the disturbances are over. It is, however, the process how these effects occurred, that has a very important meaning in considering the character of an earthquake. The steps in the beginning part of the seismographs revealed, as stated above, the occurrence of sucessive shocks. The direction of overturning also suggests the existence of different centers of disturbance. The whole earthquake seems to have begun with these successive destructions of the earth crust, starting in the northwestern end of the most deformed zone and propagated to the southeast along that zone, and finally was followed by the general panic.

6. — ROUGH ESTIMATION OF DEPTH OF THE FOCUS.

The exact determination of depth of a seismic focus is still an unsolved problen. Yet several authors tried approximate estimations and in cases of large earthquakes their origins were placed at depths of something between twenty and a hundred kilometers. Assuming straight path of the seismic ray, we can write

$$h = \frac{\Delta^2 - v^2T^2}{2vT}$$

where h is the depth of focus, Δ the epicentral distance, T the surface transit time and v the velocity of propagation near the surface. Taking 5.3 km. per sec. for v, the writer obtained the following result from data at stations around the seismic area :

Stations	Start (G. M. T.)		T	h
	km	h m s	s	km
Kumagai	96	2 58 46	14	22
Choshi	160	58 57	25	30
Mito	168	58 56	24	47
Nagano	176	58 56	24	58
Nagoya	203	59 5	33	30
Hikono	270	59 14	42	51

The time of occurrence of the initial shock at the epicenter was estimated at 2h 58m 32s from the time

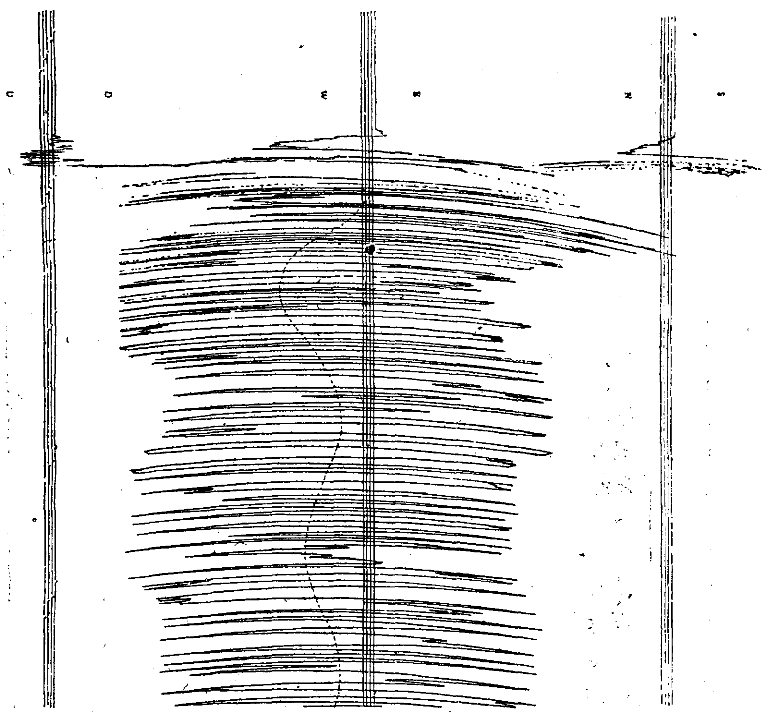

Fig. 6.

curve. The above data allow only a very rough estimation, giving the mean depth 40 km. which will perhaps reduce to some 3o km. making allowance for the curvilinear path of the seismic ray.

7. — THE SLOW CHARACTER OF THE MOTION.

The whole motion of the crust was characterised by slow movements. The seismographs gave the initial motions not very sharp, although of very large amplitudes, showing gradual deformation of the period of some five seconds at the beginning. (See Fig. 6). Every person in the seismic area felt the slow oscillations; some felt like headache and others as if they were on board a rolling ship.

8. — THE LONG PERIOD OSCILLATIONS

The seismograph at Tokyo published by Prof. Imamura (Fig. 6) showed remarkable oscillations of some 3 cm. double amplitudes on the record and of a very long period of about 110 seconds. The record of the NS component was incomplete and it is not clear whether the said motion occurred also in that direction or not. The instrumental constants of the seismograph were $V = 2$ and $T = 10$ sec. with oil dampers. Thus the magnification for earth movements of the period of 110 seconds becomes about one sixtieth. The actual double amplitudes of this earth movement must, therefore, have been 1, 2 meter. These oscillations were also shown in the EW component of the Sendai records (Fig. 7) of the same earthquake with an amplitude of the same order. At Nagasaki where the seismometer of the same type is used, the long period oscillations were not clearly shown. There the proper period of the seismometer was 3 seconds so that the magnification for the said oscillations becomes about one five-hundredth, too small to record them clearly. That this is not instrumental, cau-

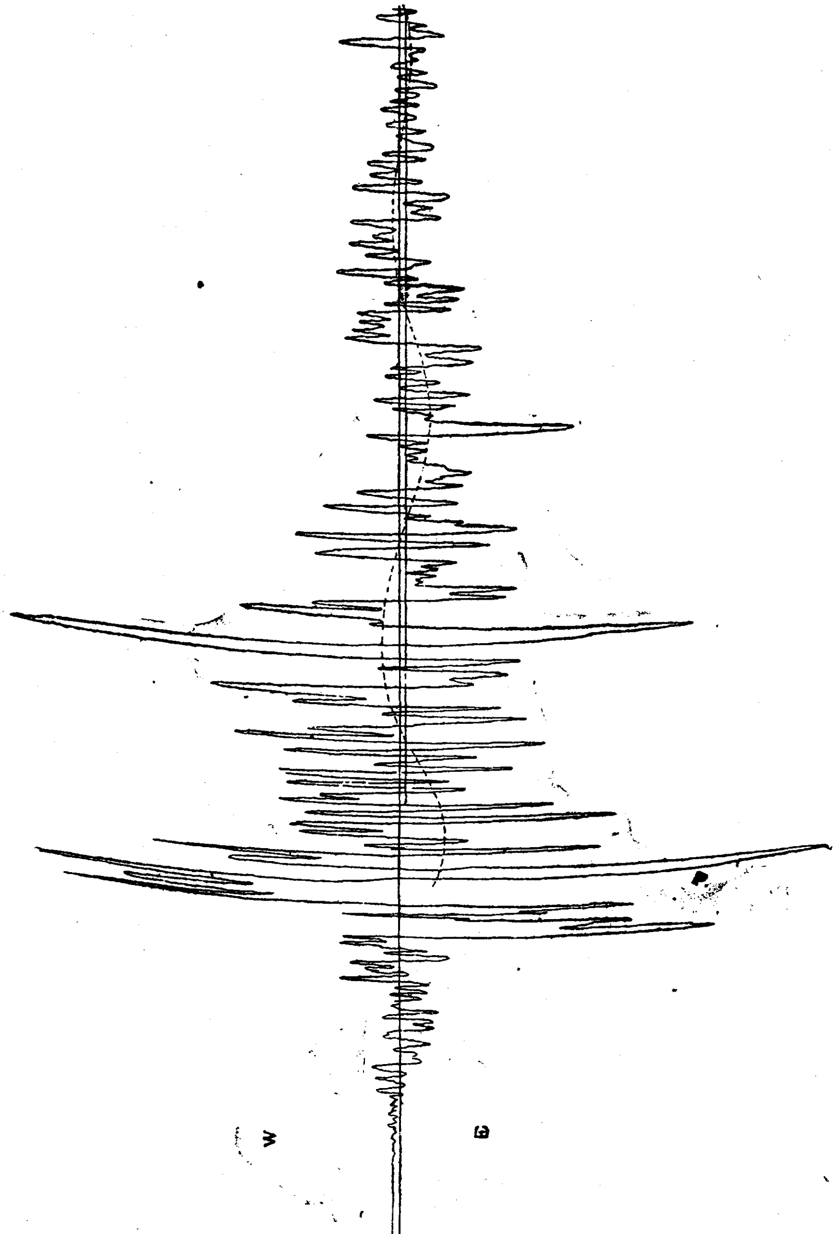

Fig. 7.

sed by the large oscillations of shorter periods, seems to be proved by the Kamigamo records of the Celebes Sea earthquake of May 27, 1914, at about 13 h, 30 m G. M. T. (Fig. 8). Here a series of long waves of about 90 sec. was clearly recorded, as is marked A and B in Fig. 8,

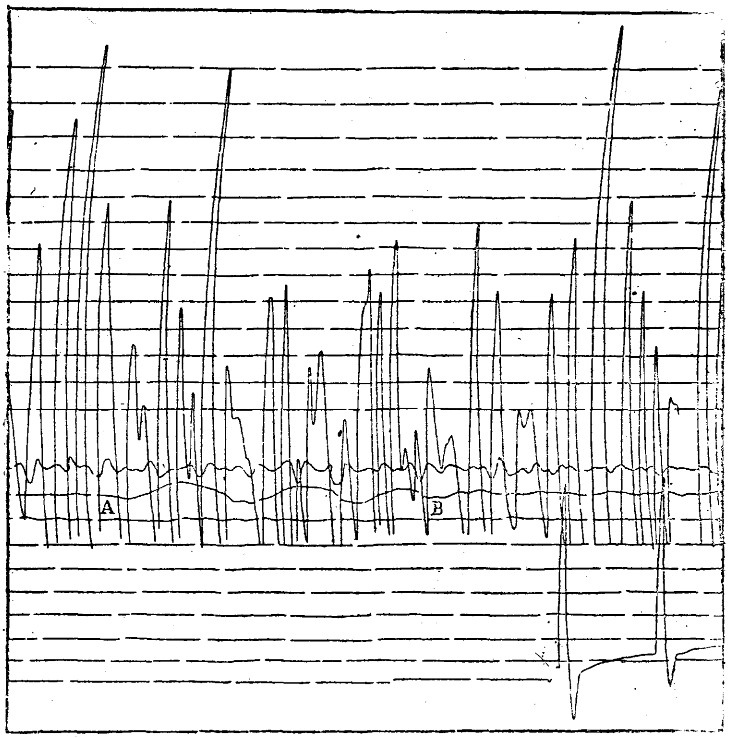

Fig. 8

in the EW component two hours later than the principal phase, when the seismograph was nearly free from oscillations of shorter periods. The double amplitude on the record was about 5 mm. The instrumental constants were T = 12 sec. and V slightly less than 200, with air dampers. Hence the magnification for the said oscillations was about 3, and the double amplitudes of the earth movement must have been about

1.7 mm. The epicentral distance was about 400 km. so that these long waves corresponded to the waves propogated along the major arc with the velocity of 4. 25 km. per sec. It is to be noticed that these oscillations seem to begin earlier than the principal motion and are transversal in the horizontal plane. We have no sufficient material at present to conclude whether the mode of oscillations of these long waves depend upon the azimuth from the origin or not.

This article was prepared under important suggestions of Prof. T. Shida of the Geophysical Institute of our University. The writer's special gratitudes are due to him.

9. — THE PLASTIC NATURE

The slow character of oscillations combined with the depth of 30 km. of the focus is of special interest to the present writer. It was discussed by Prof. Barrell that the rocks constituting the earth crust increased their strength at first with depth (1). At the depth of some 30 km. they reach their maximum strength and become about four times as strong as at the surface. Descending further, they rapidly become weaker and are easily to be yielded. When stress difference is established in the crust, it will be resisted till it overcomes the strength of the crust. It is interesting that such a destructive earthquake as that concerned here has started at the depth of some 30 km. at the zone of the maximum resistance.

It was stated above that we had rather dull start and slow oscillations of the beginning part of the Kwanto earthquake. From these phenomena the writer is inclined to consider that the catastrophe began with sudden plastic yieldings. Prof. Adams' experiments (2) on the

(1) *Journ. Geol.*, Vol, 22, N°. 8, pp. 729-741, 1914.
(2) *Journ. Geol.*, Vol. 18, N° 6, pp. 490-525, 1910.

mode of yielding of rocks seem to support this idea. When rocks are subjected to sufficient stress under ordinary pressure, fracturing will take place. But under high pressure, such as at the depth of 10 km. or more in the crust, they will be deformed in the form of plastic yielding instead of fracturing.

When crustal deformation takes place, it may be accompanied by fracturing of the superficial layer and in smaller earthquakes this fracturing may play predominant parts in the whole movements. The fact that slow yieldings were characteristic in the last Kwanto earthquake might be considered to suggest that the deeper part was affected and the plastic yieldings of that part played more important parts. The said large oscillations of very long period observed at Tokyo and Sendai were perhaps due to the mass movement of the crust above the easily yielding layer. The predominant directions of overturning in the disturbed area seem to support the above consideration.

10. — HISTORICAL RECORDS

In the history of destructive earthquakes in Japan we can pick up several which seem to have occurred on the same zone as that along which the severest changes have been observed in the last catastrophe. Their dates of occurrence are

	(Intervals)
March. 1, 1633	
Dec. 31, 1703..............................	70.8
Aug. 23, 1782..............................	78.3
Feb. 11, 1853	69.5
Sept. 1, 1923..............................	70.6

Here we notice a peculiarly regular interval of 72 years in average. Among these, that in 1703 presented nearly the same phenomena as in the last case, except that the center of catastrophe seems to have been further to the southeast, south of the Boso Peninsula. The elevation of the sea shore vas also observed in that case at the southern end and along the Pacific coast of that Peninsula. These historical records seem to suggest to us that catastrophes were repeated in that part of Japan.

II. — GEOLOGICAL NOTES

The Izu Peninsula and Oshima Island, which form the west and south boundaries of the seismic area, are of

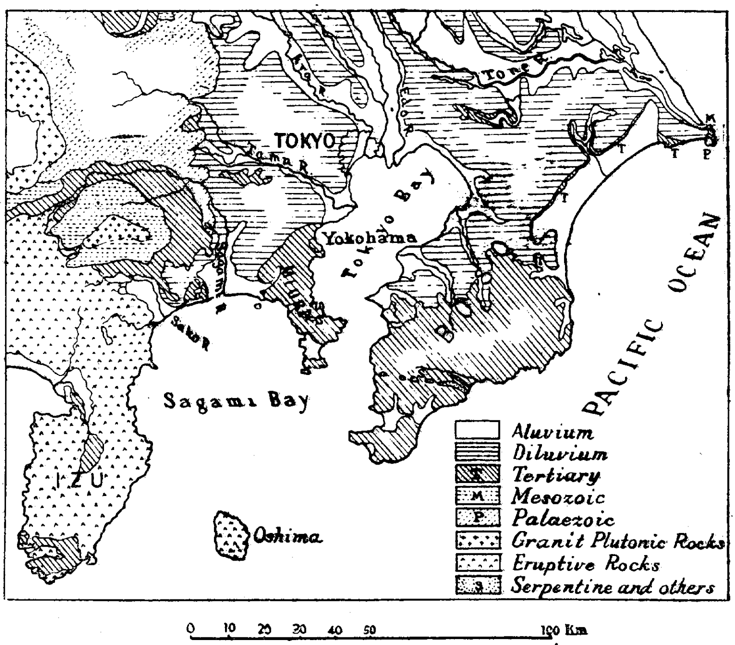

Fig. 9. — Geological map of the disturbed area.

recent eruptive rocks. At the western boundary of the Kwanto plain we observe the Tertiary and older formations with volcanic rocks and much disturbed. The main part of the Kwanto plain consists of Diluvial table lands and Aluvial lower lands along the rivers. Under the

Diluvium, Tertiary formations are often observed at the feet of cliffs of the table lands especially in the eastern parts ; even the Mesozoic and the Palaeozoïc rocks are observed at Cape Inuboe, the east end. As we pass southward into the Miura and Boso Peninsulas, the mean level of the land surface gradually rises. We first meet the younger Tertiary mudstone which has a general strike nearly in the east-west direction or slightly from northwest to southeast with local disturbances and dips to the north by rather low angle of less than 20°. Proceeding further south we meet tuffaceous shales and sandstones of older Tertiary formation, dipping steeper and steeper, till finally they become nearly vertical at the southern ends of these peninsulas, as is shown by the elevated rocks in Fig. 3. These general features of the arrangement of the rocks suggest that the southern part was gradually raised in the course of geological time.

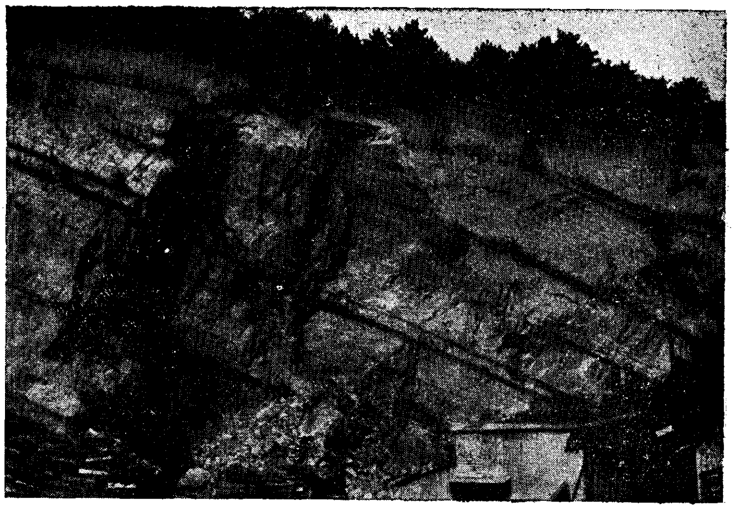

Fig. 10. — **Inclination of the Strata, near Yokosuga.**

Faults are numerous and unconformities are also observed.

Along the shore of these peninsulas, especially in the southern parts, terraces of rocks are observed each with heights of some two or three meters. The elevation of the shore by the last catastrophe has also formed flat coastal areas at places where the coast was not steep, such as at Oiso, Misaki or at the southern end of the Boso Peninsula. These terraces may be considered to be the natural records of catastrophes of the same nature as the last. The only formation of volcanic origin is the chain of diorite and other rocks crossing the Boso Peninsula in east-west direction, like a dike in large scale, at a distance of 25 km. from the southern end. The continuation is observed in the Miura Peninsula, but nearly 30 km. to the north of the former. Again, some characteristic layers of hard sandstone were observed in the northern part of the Miura Peninsula. Layers of similar appearance were also observed in the Boso Peninsula in similar relative position as in the case of the volcanic rocks. Here we might imagine the displacement of the Boso Peninsula relative to the Miura.

12. — DISTRIBUTION OF GRAVITY

The intensity of gravity in Japan has been measured all over the main part. The isostatic reduction is now going on under the care of Prof. Shinjo. The writer has drawn the isanomaly lines for the free air and Bouguer corrections. If we accept the theory of isostatic compensation the former would be the more reasonable for discussing the stress in the crust.

The most conspicuous feature of the isanomaly lines is that they run nearly parallel to the arc of the islands. We have maximum positive anomalies along the Pacific coast as well as the Japan Sea. These are of the order of 0.100 or 0.150 dynes, which are too large to be explained by Helmert's Küstenkorrektion. There are several minor areas of irregular distribution and it is interesting that the areas of minimum anomalies occur in the districts where earthquakes occur most frequently, such as the Shinano Gawa valley, the Nobi plain and others. Now, we have two districts of special importance, one in the southwestern part of Hokkaido and the other in the region under consideration.

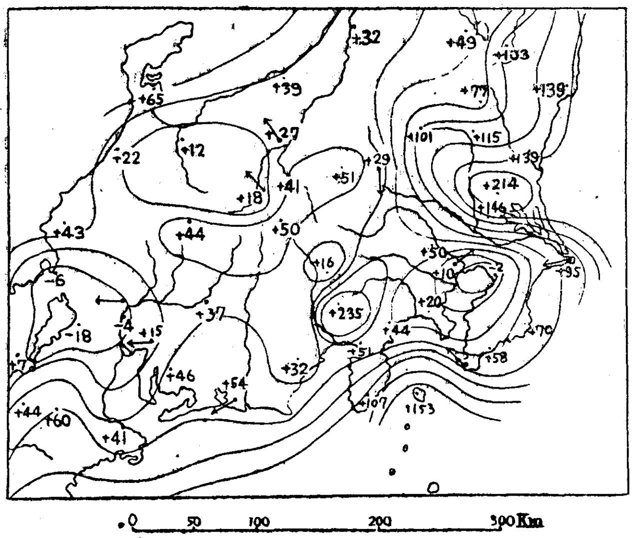

Fig. 11. — Anomaly of gravity after free air correction in central Japan, expressed in 10^{-9} dynes.

Isanomaly lines of large positive values, which run northeast along the Pacific coast from the central to the northern Japan, bulge out to the southeast at Kwanto district and embrace the minimum anomaly at the Tokyo Bay. From there toward the Miura and Boso Peninsulas, the anomaly increases to some + 0.070 dynes. The coast effects are of the order of 0.090 at the Pacific coast of the Boso Peninsula and + 0.040 at Tokyo. When corrected for this effect, we have deficiencies of the order of 0.020 all over the region concerned, suggesting that the region has slight defect of mass underneath. To the northwest of Kwanto District, we have large positive anomalies over the central region. Thus it seems natural to have the stress in the crust acting from this region of positive anomalies southeastward to the Kwanto District, in consequence of which the weakest zone undergoes yielding and the observed upheaval as well as the supposed horizontal displacement may take place. It is the writer's opinion that the Uraga Channel and the Tokyo Bay as well as the Aluvial areas along the courses of the rivers in the Kwanto plain might have been developed, to a great degree, by the successive horizontal differential displacements of different blocks formed by the faults predominating there. The defect of mass in this region might again be caused by the development of these openings partly filled by loose sediments. The energy of the dashing waves along the coast and the probable rapid denudation owing to the relatively rich precipitation might have helped in developing the said condition. Thus the defect of mass may continue to prevail there and we must expect that destructive earthquakes might be repeated in these districts so long as the said conditions continue to prevail there.

13. — CONCLUSION

The main feature of the catastrophe is the enormous elevation and depression of the Sagami Bay, separated by a line running from its northwestern shore to the southeast. The slow elevation of the land during the years before the earthquake suggests that the stress worked in raising the crust. The depression in the southern part. of the bay must be considered as the rebound following the yielding of the crust.

The horizontal displacement is not yet clear, except that the geodetic works at Mitaka suggest to us a southward displacement of about 4 meters at the southern end of the Miura Peninsula. From the nature of the change in the Sagami Bay, the writer is rather inclined to consider a displacement in the southeastward direction at least in the southern part under consideration.

The yielding began somewhere on the land near Kozu ; but the general panic followed the successive yieldings which seem to have taken place during the first few seconds, as is suggested by the records. The first yielding seems to have occurred at the depth of some thirty kilometers. The slow nature of the oscillations shows that the catastrophe was of the nature of sudden plastic yielding. Especially noteworthy are the oscillations of very long period.

The historical records suggest to us that the said zone in the Sagami Bay was the seat of repeated catastrophes. The terraces along the shore are the records of successive upheavals and show perhaps that the events like those in 1923 and 1703 were repeated even before. The fact that the further south in the peninsulas the older rocks with the steeper dip are found shows that these upheavals have continued through the recent geological age, though they might have been interrupted by temporary quiescence or resubmergence of the whole region, as suggested by the unconformities observed there.

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July 20, 1924.

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La Séismologie et les Barrages des bassins artificiels

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Il suffit de n'être pas tout à fait ignorant de la littérature sur les bassins artificiels pour savoir avec quelle précision on se rend compte aujourd'hui des efforts qui peuvent nuire à la stabilité d'un barrage, et du soin avec lequel on cherche les moyens de les combattre.

L'ingénieur se rend aisément maître, dans son projet, des charges et des poussées, mais il ne peut jamais être aussi sûr de prévoir et de contrebalancer l'intensité des forces naturelles, qui dans des cas exceptionnels peuvent dépasser tout ce que nous connaissons des coefficients de résistance.

C'est particulièrement pour les barrages en haute montagne qu'il devient nécessaire d'établir un programme certain tant au point de vue de la sécurité que des conditions économiques ; c'est là que les forces naturelles prennent leur plus grande intensité et que les difficultés de transport et d'installation d'une part, les effets du gel d'autre part, s'opposent aux règles d'une construction sûre.

Le but de cette note est de citer les forces naturelles qui « conspirent contre » la sûreté des barrages.

Ces forces sont nombreuses, et généralement produites par deux agents : la chaleur et la gravité, et par les sous-agents : la température, le vent, la hauteur barométrique, les précipitations, les séismes, les éboulements et les dislocations.

Nous négligerons quelques-unes de ces forces, par exemple celles qui sont dues aux températures, aux vents, aux gradients barométriques, car quoiqu'elles donnent lieu à des déformations d'une certaine importance, leur influence sur les barrages a déjà été bien étudiée. Le danger se limite à quelques cas particuliers, par exemple lorsque, après une congélation très forte de l'eau du lac, survient un rapide réchauffement de l'air ; lorsque le vent acquiert une vitesse de 50 mètres et que ses rafales sont périodiques ou en forme de trombes en tourbillons, lorsque les averses de pluie engendrent les crues des torrents et que ces cours d'eau descendent dans le bassin d'une façon si brusque qu'ils produisent des ondes de translation comme s'il tombait dans le lac un éboulement de terre.

L'influence sur la statique des barrages des autres agents tels que les séismes, les éboulements de terre et les dislocations a une importance bien autrement grande et c'est ici que le séismologue peut travailler côte à côte avec le technicien.

Mon opinion de séismologue est que si un barrage bâti selon toutes les règles de l'art essuie un fort tremblement de terre (par exemple du neuvième ou dixième degré de l'échelle séismique), il risque de se briser s'il se trouve que ses piliers sont appuyés sur des couches de constitution géologique différente, dont l'une ou plusieurs, anélastiques, sont inclinées sur l'horizon, penchées sur l'abîme ; fracturées, sujettes à l'infiltration des eaux et aux glissements. Il court moins de risques si ses piliers reposent sur un sol élastique, uni, homogène, sain, sec, et suffisamment étendu dans le sens horizontal.

Malheureusement, dans les hautes vallées de nos montagnes, il est rare de trouver des couches rocheuses qui n'aient les défauts mentionnés ci-dessus. Dans les gorges des Alpes et des Pyrénées, généralement choisies par les ingénieurs pour leurs barrages, les sols géologiques changent le plus souvent de nature, et c'est la roche la plus tendre, érosée par le passage des eaux courantes superficielles, qui subira l'affaissement.

Très souvent la roche la plus faible est une intrusion, que jadis avait percée la masse rocheuse environnante. Son érosion donne lieu à des gouffres à la surface, à des glissements et à des dislocations dans les couches les plus profondes.

Ces dislocations sont causées par les eaux d'infiltration qui coulent en souterrain vers le talweg, par les nombreuses cassures, non-seulement du sol qui forme le fond du lac artificiel, mais aussi par les cassures plus nombreuses de tout le bassin hydrographique dans les périodes de grandes pluies. Les eaux altèrent les éléments constitutifs des roches. Même les roches massives primitives en ressentent l'action et cela par le fait qu'elles sont fissurées aussi bien que les calcaires. Il est, en effet, difficile de trouver une couche rocheuse longue comme un barrage artificiel, qui ne soit pas, dans tous les sens, fracturée et fissurée.

La plus grande partie des gorges que nous admirons dans les paysages de montagne était jadis occupée par d'imposantes digues naturelles, digues qu'aujourd'hui nous désignerions sous le nom de « digues de masse » là où le sous-sol était rocheux, et « digues de gravité » là où le sol était morénique. Elles opposaient un obstacle aux lacs alpins préglaciaires. Eh bien, les gorges ont été creusées par le processus d'infiltration en amont et par entraînement de la matière souterraine jusqu'à l'écroulement de la voûte. Restent quelques rochers durs pour retenir le torrent et le faire précipiter en cascade. Mais un jour viendra où même ces cordons seront démolis. Alors nous nous proposons d'arrêter de nouveau l'eau par des barrages artificiels ; mais prenons garde, parce que les processus d'infiltration et d'affaissement continuent, parce que, outre le torrent superficiel, il y en a un autre souterrain qui travaille patiemment et attend l'heure propice pour passer en faisant crouler l'obstacle.

Il est possible que ces affaissements soient en relation avec les tremblements de terre. Très probablement les deux phénomènes s'influencent réciproquement : les dislocations créent les séismes locaux et les séismes, à leur tour, provoquent les dislocations locales. Les uns et les autres sont fréquents dans les Alpes et les Pyrénées, particulièrement où sont des intrusions de serpentine, lherzolitique, porphyrique, etc. Et comme ces roches figurent très souvent dans les paysages à gorges et à gouffres, nous concevons tout de suite de danger que peuvent courir les barrages bâtis sur de tels sols.

Lorsque par entraînement ou par altération se produit un affaissement, il n'est pas nécessaire qu'il soit très important pour produire de forts dommages aux barrages qu'ils supportent. Dans une construction subaérienne anélastique, en maçonnerie, telle que les ponts, les chaussées, les murs, etc., les petits mouvements du sol de base dûs aux érosions qui nous occupent n'attaquent point la consistance de l'œuvre ; mais dans une construction hydraulique qui, comme les barrages, est sujette à la pression de l'eau et est privée de tout jeu élastique dans sa longueur considérable, la plus petite lésion peut devenir dangereuse. Le péril est démontré par les trop nombreuses catastrophes survenues dans tous les pays qui ont construit des bassins artificiels dans la haute montagne.

Le problème étant d'intérêt mondial, je pense que la technique nous saura gré si nous réussissons, grâce à la séismologie, à faire cesser les préoccupations que cause le danger offert par les barrages

Un séismographe horizontal, placé sur la digue, pourra donner des indications utiles par comparaison entre les enregistrements qu'il présentera le bassin vide et le bassin plein, dans les périodes de temps sec et dans les périodes de pluies prolongées.

Si le barrage éprouve un glissement élastique ou de masse, qui l'amène à se déplacer parallèlement à lui-même, la plume n'accusera le mouvement que dans le cas où le déplacement sera rapide. Si le mouvement s'accomplit lentement, le déplacement pourra être infiniment mieux étudié au moyen des appareils dioptriques munis de réticule micrométrique dirigés sur des repères.

Mais si le barrage subit la moindre inclinaison, le séismographe devient très apte à la mesurer.

La distance *h* entre les deux supports du pendule horizontal est un facteur important dans la détermination de l'inclinaison qu'on obtiendra par la formule

$$h \text{ tang } \alpha = h\alpha = h \frac{\text{force tangentielle}}{\text{module de rigidité}}.$$

L'observation dira s'il y a eu déformation élastique (indépendante du temps) ou déformation de masse (fonction du temps) et dans ce dernier cas si la charge cesse, l'index reprendra sa position ; dans le second cas, il restera déplacé d'une façon permanente.

Plus intéressante encore sera l'étude des vibrations au sein même du barrage, ce que j'essaierai de faire comprendre par un exemple bien connu : soit un verre à boire contenant de l'eau ; une fois mis en vibration, il donne une note plus ou moins haute selon son contenu ; et en outre, si le verre est sain et suspendu librement, il fournit des vibrations très différentes de celles qu'il donnerait s'il était entamé ou soumis à des liaisons fixes. Que l'on étende cette notion aux barrages et l'on comprendra aussitôt comment, par les modes des inscriptions, il sera possible de se faire une idée de l'état de tension du barrage dans les différents cas et les divers emplacements, et surtout de vérifier si la construction se maintient en bon état.

Mais comment faire vibrer l'immense masse d'un barrage ? Oh, simplement en en laissant le soin aux microséismes naturels ou artificiels. Ces inscriptions auront un caractère constant si les tensions élastiques du barrage demeurent les mêmes, tandis que dans le cas d'une variation de charge ou d'une lésion éventuelle elles donneront des diagrammes différents.

A notre avis, il ne se produira dans le barrage de lésion petite ou grande qu'elle ne soit aussitôt enregistrée et apparaisse dans le diagramme séismographique. Pourtant nous suggérons d'utiliser aussi la composante verticale.

Grâce au séismographe, la surveillance des barrages deviendra automatique, et dans plus d'une occasion les documents obtenus constitueront autant de témoignages irrévocables pour la vérité et la justice.

La gravité et le nombre des catastrophes des barrages dans tous les pays rendent la question pressante pour les ingénieurs hydrologues ; de plus, l'installation de quelques séismographes au haut de montagnes nous renseignerait sans doute sur les petits mouvements orogéniques.

(M. Oddone avait prié la Section Internationale de Séismologie d'émettre un vœu en faveur de ces recherches).

Reçu en Octobre 1924.

Les tremblements de terre et la loi Spoerer-Maunder

Par Emilio ODDONE

Ce n'est pas la première fois que la géophysique s'occupe des relations éventuelles entre les deux phénomènes cosmiques si complexes des taches solaires et des tremblements de terre.

On peut soupçonner l'existence d'une relation à cause des faits suivants :

Les taches solaires ont une vie de jours, de semaines ou de mois comme les tremblements de terre, qui, dans chaque zone séismique, se suivent par périodes du même ordre au point de vue du temps.

Les taches solaires, quant à leur nombre et à leur surface, suivent une variation systématique dont la période est de onze années (11, 1), et on trouve des traces de cette périodicité dans les recueils séismologiques.

Les taches solaires ont leur grande fréquence aux latitudes héliographiques à 30 degrés et apparaissent aux hautes latitudes d'une manière sporadique, les tremblements de terre, même s'ils ne sont pas rares au-delà des cercles polaires, sont incomparablement plus fréquents aux basses latitudes.

J'ai été conduit à cette recherche par la lecture, dans le journal anglais « Nature », du savant article de M. G. F

Hale sur la physique des taches solaires [1]. M. Hale rappelle les cycles des taches solaires mis surtout en évidence par l'astronome M. Maunder et rappelle les lois de M.Spoerer [2]. Les taches ont des cycles de onze années et apparaissent durant leurs minimums aux hautes latitudes, tandis que les suivantes se montrent à des latitudes de plus en plus basses. En outre les premières taches précèdent de deux années la disparition des dernières taches du vieux cycle. Il en résulte un diagramme dit à « ailes de papillon » qui exprime graphiquement la loi de Spoerer.

J'ai voulu constater si, sur notre planète, la séismicité montre une marche analogue. Cela exige la supposition que l'agitation solaire, qui donne lieu aux taches, puisse être comparée à la séismicité qui donne lieu aux tremblements de terre.

On conçoit les difficultés que l'on éprouve pour estimer d'une même façon les agitations solaires et terrestres, car il s'agit de trouver pour la terre séismique des nombres correspondant à ceux que M. Wolfer donne pour le soleil.

Ce ne sont pas les catalogues séismiques qui manquent, mais il est douteux que ceux du passé soient également précis pour les différentes années et qu'ils embrassent la terre tout entière. Les lacunes deviennent moindres à mesure que les observations séismiques se sont multipliées, mais c'est précisément ce manque d'homogénéité qui fausse la comparaison entre les années récentes et les plus anciennes.

J'ai pensé qu'il vaudrait mieux travailler sur les catalogues des grands tremblements de terre, c'est-à-dire sur les macroséismes dont les ondes furent enregistrées aux observatoires d'une ou de plusieurs unités continentales.

(1) *Nature* : fascicule de Janvier 1924, N°. 105.

(2) E. W. Maunder : *Distribution of Sunspots in Heliographic Latitude* 1874-1923, Monthly Notices de la Royal Astron. Soc., Vol. 74.

La matériel est malheureusement encore très limité. J'ai consulté dans ce but le 16e, 17e et 18e report of the Committee for Seismological Investigations publié à Shide, les catalogues de l'ancien Bureau Central de Strasbourg de l'Association Internationale de Seismologie aujourd'hui dissoute, et l'International Séismological Summary publié à Oxford au nom de l'Union Internationale géodésique et géophysique récemment constituée.

Le catalogue de Shide concerne la période qui va depuis 1901 à 1910; celui de Strasbourg se rapporte aux années de 1904 à 1907 ; et celui d'Oxford va de 1913 à 1919.

Le dépouillement m'a montré que le nombre des grands tremblements de terre, à part quelques irrégularités, croît de 1901 à 1906-07, décroît vers 1908, remonte en 1910, et descend au « minimum minimorum » en 1912 (1). La marche entre 1913 et 1916 est un peu irrégulière, après quoi le nombre des tremblements de terre retrouve un grand maximum en 1918.

(1) Selon Shide 55 en 1901; et successivement 67 (1902); 81 (1903); 66 (1904); 119 (1906); 119 (1907); 86 (1908); 126 (1909); 139 (1910). Tous les bulletins séismiques confirment le minimum de 1912. Voilà, par exemple, ce qu'écrit l'Estacion Sismologica de Cartuja (Granada): el numero de terremotos indudables que homo registrado en l'ano 1912 ha sido el minor que se ha obtenido en Cartuja desde que funcionan los sismografos espanoles que llevan su nombre ».

Selon Strasbourg 29 (en 1904); 53 (1905) ; 84 (1906) ; 63 (1907) ; 50 (1908).

A noter que dans les années communes la marche est la même à Shide et à Strasbourg ; mais les chiffres absolus d'après Shide sont une fois et demie les chiffres absolus d'après Strasbourg.

Selon Oxford le nombre des très grands tremblements de terre mondiaux serait : 51 (en 1913) ; 60 (1914) ; 63 (1915) ; 50 (1916) 61 (1917) ; 75 (1918) ; 42 (1919). Le nombre des enregistrements moins grands, mais toujours notables, selon Oxford, serait évidemment plus fort, précisément : 79 (1913) ; 60 (1914) ; 91 (1915) ; 61 (1916) ; 269 (1917) ; 346 (1918) ; 289 (1919).

Il faut donc se garder de mettre ces chiffres en une chaîne unique avec les précédents de Shide et de Strasbourg.

Entre les deux minimums séismiques de 1901 et 1912, et de même entre les maximums de 1906-07 et 1918, s'étend la période de onze années. Une exception marque l'année 1910 qui accuse un maximum paraissant s'écarter de la marche générale du phénomène.

Quant à l'activité des taches solaires, le monde savant sait que les nombres de M. Wolfer ont leurs plus petites valeurs en 1901 et 1912, et leurs valeurs les plus grandes en 1906 et 1917.

Sous réserve des surprises que les recherches futures pourront apporter à la question (et le susdit maximum d'activité séismique en 1910 en est une), nous pouvons déjà apporter quelques réponses provisoires aux questions qui font le sujet de cette note :

1° Les tremblements de terre et les taches solaires, indices respectifs de l'activité terrestre et solaire, éprouvent une variation systématique dont la période est de onze années.

2) La marche des nombres des grands téléséismes annuels n'a pas la régularité de celle des taches solaires ; il n'y a pas non plus une coïncidence exacte de phase avec elles ; pourtant les allures des deux phénomènes ont des parallélismes très frappants.

3) Quant aux lois de M. Spoerer, nous n'avons pas encore pu les vérifier. Nous avons observé que de 1904 à 1907 les latitudes épicentrales moyennes diminuent leurs valeurs (34°, 3 ; 28° ; 25°, 3 ; 18°, 8) ; et dans la période de 1915 à 1918 (séparée de la précédente par l'intervalle de onze années) les latitudes moyennes des épicentres, selon la première série d'Oxford, vont encore en décroissant, (27°, 6 ; 22°, 3, ; 21°, 2 ; 20°, 5). Quelque chose rappelle donc la loi de Spoerer, mais il y a des divergences et par exemple selon la seconde série d'Oxford, les latitudes moyennes, de 1915 à 1918, n'ont pas de marche régulière (30°, 7 ; 25°, 9 ; 28°, 2 ; 28°, 2).

Il est désirable que cette recherche soit continuée.

Sachant que plus d'un événement sur la terre éprouve des variations suivant la période des taches solaires, il n'est pas très surprenant que la séismicité soit assujettie aussi à cete période. La séismicité pourrait avoir, avec les phénomènes solaires, une dépendance en sous-ordre, en relation par exemple avec les pluies, dont l'intensité est en relation avec la latitude, etc.

Si les investigations futures confirment cette extension aux séismes de la périodicité des taches solaires et de la loi des latitudes, ce ne sera pas la valeur de l'explication qui fera perdre au sujet son importance, aussi grande soit au point de vue scientifique qu'au point de vue pratique, marquant un premier pas vers la prévision des séismes. Si au contraire la preuve vient à faire défaut, nous aurons appris, une fois de plus, la nécessité de nous garder de ce que les météorologistes anglais appellent « the long arms of the coincidences ».

Bureau Météorologique et Géophysique de Rome.

30 juin 1924

Sur l'arrivée des ondes séismiques à l'antipode et sur la détermination de la profondeur du foyer d'un tremblement de terre

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On the arrival of Earthquake Waves at the Antipodes, and on the Measurement of the Focal Depth of an Earthquake

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1. A paper with the above title forms N° 1, Vol 1, of the Geophysical Supplement to the Monthly Notices of the Royal Astronomical Society and bears the date March 1922. Copies were distributed to all the stations which were at that time sending seismograph readings to Oxford; and other copies can be purchased from Messrs. Wheldon and Wesley Ltd 29, Essex St. Strand, London, at the price of Is 6d. But Professor Rothé thinks that it might be welcome to seismologists that an account of these matters should be given in the publications of the Geodetic and Geophysical Union; and in

deference to this opinion (expressed at the Madrid meeting of the Section and approved by those assembled) I repeat certain portions of the above paper, with additions suggested by the experience of the last 2 or 3 years.

Formula for Arrival of Waves at antipodes of Epicentre.

2. The first point is that for most earthquakes the time of the first disturbance near the antipodes is

$$[P] = 20^m 17^s - (180 - \Delta)^2 \times 0^s{,}0235.$$

The table equivalent to this formula has been given several times but may be repeated here for completeness. Δ is of course the distance from the epicentre in degrees of arc.

Table for [P]

Δ	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
°	m s	s	s	s	s	s	s	s	s	s
90	17 7	11	15	19	23	27	31	35	39	43
100	17 47	50	54	58	61	65	68	72	75	79
110	18 22	25	28	31	34	38	41	44	47	50
120	18 52	55	58	61	63	66	68	71	74	76
130	19 18	21	23	25	28	30	32	34	36	38
140	19 39	41	43	45	47	48	50	51	53	54
150	19 56	57	59	60	61	62	63	65	66	67
160	20 8	9	9	10	11	12	12	13	14	14
170	20 15	15	16	16	16	16	17	17	17	17

3. This wave has been denoted [P]. It is not P itself, although near the actual anticentre ($\Delta = 180^\circ$) it seems possible that P and [P] may arrive together. But near $\Delta = 90^\circ$ [P] arrives about the same time as PR_1, the time for which is

For Δ =	90°	100°	110°	120°
PR_1 =	$17^m 6^s$	$18^m 14^s$	$19^m 18^s$	$20^m 24^s$
[P] =	17 7	17 47	18 22	18 52
P =	13 16	14 11	14 57	15 42

It is thus always easy to separate [P] from P ; and also from PR_1 except when Δ is near 90°. But [P] is chiefly observed when $\Delta > 130^\circ$.

4. The above formula and table were derived by trial and error, as explained in the paper quoted; and it seems scarcely necessary now to give the earlier experimental stages. We may perhaps repeat the example given in the former paper.

1913 Nov 10 d 21 h

Excess of observed [P] *over above formula*

Station	Inst.	Δ	O — C	Station	Inst.	Δ	O — C
Ksara........	Ma	136°.2	+ 6s	Heidelberg....	—	145°.3	— 4s
Breslau.......	W	140.6	— 4	Laibach......	G	145.4	+ 7
Hamburg.....		141.2	+ 1	Innsbruck....	Ma	145.9	+ 1
Budapest.....	W	142.1	+ 3	Triest........	W	146.0	+ 2
Eskdalemuir .	G	142.3	+ 5	Padova	V	147.1	+ 6
Vienna.......	W	142.9	+ 2	Monte Cassino	Ca	148.9	+ 9
Graz..........	W	144.2	+ 1	Pompei.......	OA	149.1	+ 10
Aachen	W	144.8	— 3	Moncalieri....	S	149.2	— 6
Zagreb.......	W	145.0	+ 4	Granada	Bif	160.0	+ 17

Here there are a number of stations with various instruments, all recording [P] within a few seconds of the time (C) indicated by the formula.. The algebraic mean of the errors is + 3.0 s. and the numerical mean is ± 5.0 s.

Systematic differences from formula

5. Compare now the case of

1919 Nov 20d 14 h 11 m 38 s : 13° S 167° E

Excess of [P] *over above formula*

Station	Δ	O — C	Res	Station	Δ	O — C	Res
Hamburg	135°.5	— 19s	+ 9s	Moncalieri....	143°.4	— 32s	— 4s
Vienna	137.1	— 28	0	Rocca di Papa	143.5	— 27	+ 1
Uccle.........	139.6	— 29	— 1	Marseille	145.8	— 23	+ 5
Strasbourg....	140.4	— 46	— 18	Barcelona	148.4	— 24	+ 4
Zurich	141.1	— 37	— 9	Tortosa	149.7	— 27	+ 1
Paris.........	141.9	— 29	— 1	Algiers.......	152.1	— 26	+ 2
Besançon.....	142.2	— 13	+ 15	Coimbra	152.5	— 97	— 69
Florence.....	142.8	— 32	— 4	Granada	154.3	— 19	+ 9
Pompei.......	143.2	— 34	— 6	San Fernando.	155.7	— 53	— 25

Here the algebraic mean is about + 28 s (the exact value depending on the treatment of Coimbra); and if we subtract this mean value, the residuals (shewn in the adjacent columns) have a mean numerical value ± 7 s, if we allow an error of 60 s in Coimbra .

Interpretation of Systematic differences.

6. These two examples suffice perhaps to shew

(*a*) that the variable part of the formula

$$-(180 - \Delta)^2 \times 0^s.0235$$

though susceptible of improvement. is a very fair first approximation. But that

(*b*) The constant 20 m 17 s does not suit all earthquakes : E. g. for that of 1919 Nov 20d it is nearly 30 s in error, the arrival of [P] being systematically this amount earlier than usual. Now the argument is that the focus for this earthquake is deeper seated than usual, and therefore nearer the antipodes (by about 0.030 of the Earth's radius).

7. A few weeks earlier we have the case of

1919 Oct. 12 d 21 h 48 m 15 s : 4°.0 S. 101°.0 E

Station	Δ	O — C
Georgetown	145°.1	+ 11ˢ
La Paz	156.8	+ 14

There are only two stations, but they are in good accord in shewing that [P] arrives *later* than usual : so that the focus is further away from the antipodes, i. e. nearer the epicentre, i. e. not so deep as usual.

8. These cases of depth *above* normal are rarer than those *below* normal but several have been noted in the reductions, and a list of them is given in the introduction to the International Summary for Jan.-Mar. 1920. They

may be repeated here for convenience. Depths *below* normal are reckoned positive (Group III) and *above*, negative (Group I) the excess or defect being reckoned in fractions of the Earth's radius.

GROUP I

Date	Defect	Date	Defect
1914 June 26............	— .010	1918 Sept. 8............	— .030
1916 Jan. 1.............	— .009	1918 Sept. 12............	
1916 Oct. 3.............	— .021	1919 April 30............	— .015
1916 Oct. 20............	— .021	1919 May 6.............	— .030
1918 July 8.............	— .010	1919 May 29	— .020
1918 Sept. 7............	— .030	1919 Oct. 12............	— .020

It will be seen that there are 4 cases of defect by 0.030 of the earth's radius so that if we admit these as approximately correct, the normal depth must exceed 0.030 ; hence 0.040 = 160 miles or 200 km is a reasonable estimate for the focal depth of the great majority of earthquakes (Group•II, when the depth is normal).

9. Below them comes Group III, as follows :

GROUP III

Date	Excess	Date	Excess
1913 Nov. 10............	+ .033	1919 Mar. 1.............	+ .030
1914 Feb. 26............	+ .053	1919 Mar. 2.............	+ .020
1915 Jan. 5.............	+ .034	1919 Mar. 2.............	
1916 June 21............	+ .060	1919 Mar 9.............	
1916 Sept. 3............	+ .035	1919 Mar. 13............	+ .070 ?
1917 April 21...........	+ .033	1919 Mar. 16............	+ .015
1918 Feb. 7.............	+ .025	1919 Mar. 16............	
1918 April 10...........	+ .070	1919 April 17...........	+ .010
1918 May 22............	+ .050	1919 May 3.............	+ .005
1918 May 25............	+ .015	1919 June 1.............	+ .040
1918 Nov. 18............	+ .030	1919 Aug. 18............	+ .050
1918 Nov. 23............		1919 Aug. 18............	
1918 Dec. 14............	+ .030	1919 Oct. 27............	+ .040
1918 Dec. 25............	+ .070	1919 Nov. 6.............	+ .010
1919 Jan 1.............	+ .030	1919 Nov. 20............	+ .040

10. Further details for any of these earthquakes can of course be obtained by referring to the appropriate numbers of the *International Summary*, or its predecessors the Shide and Oxford Bulletins : but the effects of depth are only fully worked out for the later dates (since April 1917).

Effect of focal depth on other stations ($\Delta = 0^o$ to 90^o).

11. Now this explanation of the large systematic deviations from the formula, (as due to variation in focal depth) would not be of much value if it stood alone.

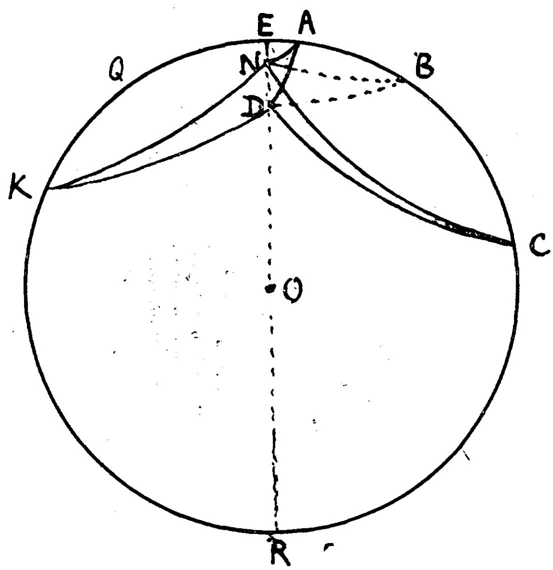

Fig. 1.

But it is supported by the evidence of stations near the epicentre. Let us consider what happens when the shock occurs, not at the normal depth which we will denote by N (Fig. 1) but deeper at D. As regards the antipodes R we have already pointed out that the path D R being shorter than N R the wave [P] will arrive earlier than if it came from N according to the tables. And the same will be true for the regular P and S waves arriving at a station such as C far from the epicentre E. But a station A close to the epicentre is nearer N than D, and consequently the P and S waves will arrive at A *later* than the tables (constructed for N) indicate. Between A and C there will be some point B equally near N and D (as judged by the arrival of P and S.)

12. The stations close to the epicentre such as A are rare, and we usually have to consider those like C and K at some distance from the epicentre. At either of these both S and P will arrive too early (according to the tables). If they had come from N they would have indicated (through use of the tables) the epicentral distances Δ = CBE and Δ = KQE, assuming the observations accurate. But since they come from D they both indicate distances shorter than these, the sum of which does not amount to the whole arc CEK, but leaves a gap near E. If then our hypothesis is correct, then whenever the stations near R assign [P] too early, the stations like C and K on opposite sides of the epicentre should both assign Δ too small. If we try to find the epicentre in the familiar way by drawing circles on a globe, with C and K as centres and radii the values of Δ found from S — P, then the circles will no longer intersect in a point, but will leave an area blank surrounding the epicentre. This is a crucial test of the hypothesis, and it does not fail us. If it did, the hypothesis would be valueless.

13. The first case of the kind which attracted attention was that of 1917 April 21, and it is worth repeating. On p 23 of the British Assoc. Bulletin for March and April 1917 the T_0 is adopted as April 21 d 0 h 49 m 18 s : but it is shown on p. 3 that this must be wrong, on the testimony of 20 good observations (including Pulkovo, De Bilt, Uccle, Paris, etc). The fact is, before the consequences of the abnormal focal depth were realized, they

were slurred over by compromises, one of which was the adoption of a spurious T_0. The corrected T_0 is given on p. 6 of that bulletin and should be 23 sec. greater, that is 21 d 0 h 49 m 41 s. Making this correction, and retaining only stations with fairly complete observations the records of p. 23 of the Bulletin would stand as follows

1917 April 21 d 0 h 49 m 41 s

	Δ	Az	P	O — C	S	O — C
			m s	s	m s	s
Calcutta.........	21.4	129	4.36	— 21	8.13	— 40
Pulkovo.........	33.8	324	*i* 6.39	— 24	*i* 11.53	— 45
Zagreb.........	40.8	300	*i* 7.31	— 30	*i* 13.35	— 43
Zi-ka-wei.........	42.0	83	7.45	— 26	13.50	— 45
Rocca di Papa...	43.9	294	7.59	— 26	14.18	— 43
Moncalieri.......	46.6	300	*i* 8.23	— 21	*i* 14.55	— 41
De Bilt..........	46.8	310	*i* 8.25	— 21	*i* 15.6	— 32
Uccle............	47.6	308	8.28	— 23	*i* 15.12	— 37
Paris............	49.1	306	*i* 8.39	— 22	*i* 15 34	— 33
Manila..........	50.1	103	*e* 8.55	— 13	—	—
Osaka...........	51.5	72	8.57	— 26	18.1	(+ 83)
Mizusawa........	54.0	65	9.12	— 21	18.38	(+ 89)

14. Other stations might be added, but these will suffice to shew the universal desire to have the epicentre nearer, as indicated by the consistently negative residuals. Osaka and Mizusawa are probably 2 min. in error for S and should be — 37 s and — 31 s. The stations are in various azimuths 65°, 72°, 83°, 103°, 129° ; 294°, 300°, 300°, 306°, 308°, 310°, 324°. The mean of the first five is 90° : that of the last 7 is 306°, differing from 90° by 216° (or 144°). It is impossible to move the epicentre along the surface of the earth so as to be nearer both sets. When, such cases occurred before any allowance for depth of focus was suspected the best compromise possible was made — the epicentre was moved nearer the better observed set of stations, leaving the others as affected by some unknown source of error : and at the same time T_0 was altered so as to reduce the

negative character of the residuals, though at the expense of making those of S inconsistent with those of P. In the 10 stations with complete observations given above the mean P residual is — 24.0 s and the S residual — 39.6 s, which are approximately in the ratio 1 : 1.8 as they should be. [The departure from 1 : 1.8 is of course due to the omission of some stations used for determining T_0 from the above selected list].

Quantitative Test of the Hypothesis of Focal Depth

15. We thus see that the stations near the epicentre are affected qualitatively in the right way : but we must now examine whether the *amount* of the effect on these stations corresponds with that indicated by the antipodal stations. This might have needed a troublesome investigation or might not have been possible at all. Fortunately, however, exactly the information required had already been provided by the devoted work of the late Professor C.-G. Knott, of Edinburgh. He published it in the *Proceedings of the Royal Society of Edinburgh* of which Society he was Secretary. The title of his paper is « The Propagation of earthquake Waves through the Earth and Connected Problems » (Proc R.S.E., 39, part II, n° 14 : session 1918-19). This paper is well worth reading. [If it is not generally accessible to seismologists, Professor Rothé might possibly reprint it in the publications of the section ? Perhaps those who would welcome this course would kindly let him know. There are other papers, such as those of Galitzin published after his death, which might also be reprinted perhaps]. The important part of it for our present purpose is contained in the tables at the end, parts of which we reprint here for convenience of reference.

16. Professor Knott traces the course of a ray such as ADB (fig. 2). Starting from an origin *on the surface* at A, he denotes the angle EAF by φ, which is also the angle DBE when the ray reaches the surface again at B. Any point F on the ray is defined by the angle ACF, subtended at the centre of the earth (considered spherical) by the arc AF : or alternatively by the dis-

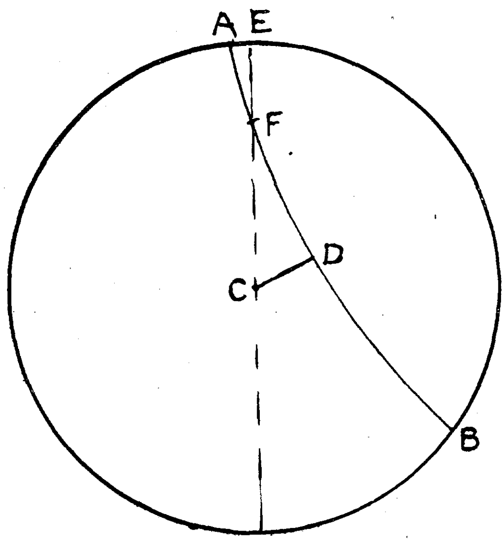

Fig. 2.

tance CF measured in units of the earth's radius. The tables give the connection between CF $= r$, ACF $= \theta$, and t the time along AF. There is symmetry about the radius CD to the mid point of the arc, and something could be gained by referring θ to this line as initial line ; but we will retain Knott's method of presentation, which has other advantages.

P *rays*

$\varphi = 48^{\circ}.41'$

r	θ (° ′)	t (s)
1.00	0.0	0.0
.97	2.27	43.0
.94	6.54	102.6
.935	9.43	135.7
.94	12.31	168.8
.97	16.58	228.4
1.00	19.25	271.4

$\varphi = 42^{\circ}.32'$

r	θ (° ′)	t (s)
1.00	0.0	0.0
.97	1.54	37.0
.94	4.35	77.8
.91	9.53	140.3
.905	13.14	176.0
.91	16.36	211.7
.94	21.54	274.2
.97	24.35	315.0
1.00	26.29	352.0

$\varphi = 30^{\circ}.18'$

r	θ (° ′)	t (s)
1.00	0.0	0.0
.97	1.8	29.8
.94	2.32	58.7
.91	4.20	87.5
.88	6.44	118.4
.85	10.3	153.1
.82	16.24	208.3
.815	20.28	240.4
.82	24.32	272.5
.85	30.56	327.7
.88	34.8	362.4
.91	36.37	393.3
.94	38.24	432.1
.97	39.49	452.0
1.00	40.57	480.8

$\varphi = 26^{\circ}.39'$

r	θ (° ′)	t (s)
1.00	0.0	0.0
.97	0.59	28.8
.94	2.9	55.8
.91	3.35	82.0
.88	5.22	108,4
.85	7.38	135.8
.82	10.42	166.2
.79	15.19	204.6
.77	23.38	266.0
.79	32.37	327.4
.82	37.14	365.8
.85	40.18	396.2
.88	42.34	423.6
.91	44.21	450.0
.94	45.47	476.2
.97	46.57	503.2
1.00	47.56	532.0

$\varphi = 24^{\circ}.38'$

r	θ (° ′)	t (s)
1.00	0.0	0.0
.97	0.53	28.0
.94	1.57	54.4
.91	3.15	79.9
.88	4.51	105.0
.85	6.51	130.7
.82	9.26	157.9
.79	12.57	188.8
.76	18.48	232.1
.745	28.50	297.8
.76	38.32	363.5
.79	44.43	406.8
.82	48.13	437.7
.85	50.49	464.9
.88	52.49	490.6
.91	54.25	515.7
.94	55.43	541.2
.97	56.4[illegible]	567.6
1.00	57.40	595.6

$\varphi = 24^{\circ}.18'$

r	θ (° ′)	t (s)
1.00	0.0	0.0
.97	0.52	27.9
.94	1.55	54.2
.91	3.12	79.6
.88	4.46	104.5
.85	6.44	129.9
.82	9.15	156.5
.79	12.35	186.6
.76	17.55	226.5
.735	32.46	322.6
.76	47.37	418.7
.79	52.56	458.6
.82	56.18	488.7
.85	58.48	515.3
.88	60.45	540.7
.91	62.20	565.6
.94	63.37	591.0
.97	64.40	617.3
1.00	65.32	645.2

$\varphi = 24^{\circ}.3'$

r	θ (° ′)	t (s)
1.00	0.0	0.0
.97	0.51	27.9
.94	1.53	54.1
.91	3.9	79.3
.88	4.42	104.0
.85	6.36	129.1
.82	9.3	155.4
.79	12.17	184.7
.76	17.15	222.3
.725	36.55	350.4
.76	56.36	478.5
.79	61.34	516.1
.82	64.48	545.4
.85	67.15	571.7
.88	69.10	596.8
.91	70.42	621.5
.94	71.58	646.7
.97	73.0	672.9
1.00	73.51	700.8

S *rays*

$\varphi = 42^{\circ}.13'$

r	θ	t
	° ′	s
1.00	0.0	0.0
.97	1.51	64.7
.94	4.22	133.4
.91	9.32	237.5
.905	12.49	304.5
.91	16.6	371.5
.94	21.16	475.6
.97	23.47	534.3
1.00	25.37	609.0

$\varphi = 29^{\circ}.40'$

r	θ	t
1.00	0.0	0.0
.97	1.7	53.4
.94	2.31	104.9
.91	4.17	156.6
.88	6.36	211.0
.85	9.53	273.3
.82	16.14	367.9
.815	20.32	428.4
.82	24.50	488.9
.85	31.11	583.5
.88	34.28	645.8
.91	36.47	700.2
.94	38.33	751.9
.97	39.57	803.4
1.00	41.4	856.8

$\varphi = 26^{\circ}.23'$

r	θ	t
	° ′	s
1.00	0.0	0.0
.97	0.58	51.4
.94	2.10	100.2
.91	3.37	147.9
.88	5.25	196.2
.85	7.48	246.5
.82	11.6	303.7
.79	16.18	379.5
.77	27.5	516.9
.79	37.51	654.3
.82	43.3	730.2
.85	46.21	787.3
.88	48.44	837.6
.91	50.32	885.9
.94	51.59	933.6
.97	53.11	982.4
1.00	54.9	1033.8

$\varphi = 24^{\circ}.54'$

r	θ	t
	° ′	s
1.00	0.0	0.0
.97	0.54	50.6
.94	2.0	97.8
.91	3.21	144.1
.88	5.0	189.1
.85	7.7	236.2
.82	9.53	287.0
.79	14.3	350.1
.76	20.7	431.1
.73	31.21	569.4
.725	38.13	650.8
.73	45.6	732.2
.76	56.20	870.5
.79	62.23	951.5
.82	66.34	1014.6
.85	69.20	1065.4
.88	71.27	1112.5
.91	73.6	1157.5
.94	74.26	1203.8
.97	75.33	1251.0
1.00	76.27	1301.6

$\varphi = 21^{\circ}39'$

r	θ	t
1.00	0.0	0.0
.97	0.46	49.1
.94	1.41	94.9
.91	2.48	138.5
.88	4.8	180.8
.85	5.47	227.7
.82	7.49	265.3
.79	10.21	310.0
.76	13.33	359.2
.73	17.22	412.9
.70	22.1	473.9
.67	28.15	548.8
.64	39.26	671.0
.635	46.16	742.5
.64	53.5	814.0
.67	64.16	936.2
.70	70.30	1011.1
.73	75.9	1072.1
.76	78.58	1125.8
.79	82.10	1175.8
.82	84.43	1219.7
.85	86.45	1262.3
.88	88.23	1304.2
.91	89.44	1346.5
.94	90.50	1390.1
.97	91.46	1435.9
1.00	92.31	1484.0

17. This is only a fraction of the total information as to the course of these rays printed by Professor Knott, but it will suffice for our purpose.

We see that when $\varphi = 48^{\circ}41'$, the whole arc θ is $19^{\circ}\ 25'$ and the time 271.4 s is the time from a focus on the surface to a point for which $\Delta = 19^{\circ}\ 25'$ is 271.4 s, approximately as given in the tables adopted in the

International Summary. [These tables formed the basis of Prof. Knott's work and he assumed that they applied to a focus close to the surface. On the hypothesis now advocated this is incorrect : the tables suit the normal earthquake, which has a focus of origin at a sensible depth, say 0.040 of the earth's radius : and Knott's work will thus require modification. But it gives us a first approximation to the results we required]. But we also see that if the ray started at a depth 0.030 below the surface then the apparent Δ would be $19^{\circ}\ 25' - 2^{\circ}\ 27'$ or $16^{\circ}\ 58'$, and the time taken would be 271.4 s — 43.0 s = 228.4 s : and similarly for the other P rays calculated. We have only to subtract the first line from the last in order to adapt the calculations to a focus 0.03 below the surface. We get at once the following table for P and S (the rays are a little different in the two cases).

Times for P *and* S *with Focal depth* 0.030

Δ	P	Corresp Δ_0	$\Delta_0 - \Delta$	Δ	S	Corresp Δ_0	$\Delta_0 - \Delta$
° ′	s	°	°	° ′	s	°	°
0.51	27.9	1.8	+ 1.0	0.46	49.1	1.7	+ 0.9
1.8	29.8	2.0	+ 0.9	1.7	53.4	1.9	+ 0.8
2.27	43.0	2.7	+ 0.3	1.51	64.7	2.4	+ 0.6
16.58	228.4	15.7	— 1.3	23.46	534.3	23.0	— 0.8
24.35	315.0	22.8	— 1.4	39.57	803.4	36.9	— 3.0
39.49	456.0	37.2	— 2.2	53.11	982.4	50.3	— 2.9
46.57	504.2	43.6	— 3.3	75.33	1251.0	72.1	— 3.5
56.47	567.6	53.3	— 3.5	91.46	1435.9	88.4	— 3.4
64.40	617.3	60.7	— 4.0				
73.0	672.9	69.3	— 3.7				

18. The figures for small values of Δ are taken direct from Knott's results, those for the larger values by subtraction as above. Now if the observed time for P is 27s.9, we find in the tables that the corresponding value of Δ is $1^{\circ}.8$, which is entered in the column « Corresp Δ_0 ». The differences $\Delta_0 - \Delta$ are positive at first and negative later, as explained in § 11, and we have now got an appro-

ximate measure of the *amount* of this effect, due to a focal depth 0.030. Just in the same way, by subtracting the second line of each table, we can get the effect of a focal depth 0.060. The residuals were smoothed and interpolations made by a graphical process ; and the values adopted for use are as follows.

Values of $\Delta_0 - \Delta$

Focal depth in units of Earth's radius

Δ	0.010	0.015	0.020	0.030	0.040	0.050	0.060	0.070
0°	+ 0°.3	+ 0°.4	+ 0°.6	+ 1°.0	+ 1°.5	+ 2°.0	+ 2°.6	+ 3°.2
5	0.0	0.0	0.0	0.0	+ 0.1	+ 0.3	+ 0.5	+ 0.7
10	− 0.1	− 0.2	− 0.2	− 0.4	− 0.5	− 0.6	− 0.7	− 0.8
15	− 0.2	− 0.4	− 0.5	− 0.8	− 1.0	− 1.3	− 1.6	− 1.9
20	− 0.4	− 0.6	− 0.8	− 1.2	− 1.6	− 2.0	− 2.4	− 2.8
25	− 0.5	− 0.8	− 1.1	− 1.6	− 2.1	− 2.6	− 3.1	− 3.6
30	− 0.7	− 1.0	− 1.4	− 2.0	− 2.6	− 3.2	− 3.7	− 4.3
35	− 0.8	− 1.2	− 1.6	− 2.3	− 3.0	− 3.6	− 4.2	− 4.8
40	− 0.8	− 1.3	− 1.7	− 2.5	− 3.3	− 4.0	− 4.7	− 5.4
45	− 0.9	− 1.4	− 1.9	− 2.8	− 3.6	− 4.4	− 5.1	− 5.9
50	− 1.0	− 1.5	− 2.1	− 3.1	− 4.0	− 4.8	− 5.5	− 6.3
55	− 1.1	− 1.7	− 2.3	− 3.4	− 4.4	− 5.2	− 5.9	− 6.7
60	− 1.2	− 1.8	− 2.4	− 3.6	− 4.6	− 5.5	− 6.2	− 7.0
65	− 1.2	− 1.9	− 2.5	− 3.7	− 4.7	− 5.7	− 6.5	− 7.3
70	− 1.3	− 2.0	− 2.6	− 3.8	− 4.9	− 5.9	− 6.8	− 7.6
75	− 1.3	− 2.0	− 2.6	− 3.9	− 5.0	− 6.0	− 7.0	− 8.0
80	− 1.3	− 2.1	− 2.7	− 4.0	− 5.1	− 6.2	− 7.2	− 8.3
85	− 1.4	− 2.1	− 2.7	− 4.1	− 5.3	− 6.4	− 7.4	− 8.4
90	− 1.4	− 2.1	− 2.8	− 4.2	− 5.4	− 6.5	− 7.5	− 8.4

An example fully worked out

19. We may now consider the use of this table, for any given earthquake. First form from the observed values of S — P as good as possible a value of T_0. Abnormal depth of focus will not affect this determination, for though the S and P waves may come from D (in Fig 1) instead of from N, they remain in the ratio 1.8 to 1. (approx.) : their difference will thus be 0.8 P (approx) from which P can be deduced and T_0 inferred. This point, that T_0 can be inferred with fair accuracy even when the focus is abnormal, is of great importance. Now make a rough estimate of the epicentre and of the Δ for all stations near

the anticentre. These will give observations of [P] and shew the systematic deviation from the tables, say — D sec. Then we may assume a focal depth .030 D/23 : i. e. every — 23 sec corresponds to a depth 0.030. [This rule is however not quite correct; for it was deduced from Knott's results which are based on the erroneous assumption that the normal focus is close to the earth's surface. We will return to this point later.]

20. Thus take as an example 1918 April 10 d 2h 3m 44s. On p. 45 of the International Summary for 1918 an approximate solution is given. There is only one antipodal station, viz La Paz, which gives the [P] residual [— 67 s]. But the La Paz observations are usually so good that we may trust even this single residual with some confidence. When — D = — 67 s, then 030 D/23 = .090. This is probably too large, and the excess is probably due to the erroneous position of the provisional epicentre. On the opposite page (p 44) it will be seen that when the definitive reduction is made the residual for La Paz is reduced to [— 56 s] which gives a focal depth .073, in good agreement with that adopted, viz .070. A certain amount of trial and error can scarcely be avoided in such work but the principle remains the same.

21. Having now a provisional epicentre, and adopting cautiously the provisional depth .070, we take from the last column of the above table the corrections for that depth and apply them to the calculated Δ. It will be convenient to collect the observations according to azimuth round the adopted epicentre 40°.0 N 110°.0 E

Group I

Station	Az	Δ	Corr	Δ_p	Δz	O — C
Zi-ka-wei	130°	12°.8	— 1°.4	13°.1	12°.2	+ 1°.3
Taihoku	143	17.8	— 2.4	16.8	—	+ 1.4
Manila..........	156	27.2	— 3.9	24.7	24.5	+ 1.3
Batavia	184	46.3	— 6.0	46.4	46.4	+ 6.1
Riverview	147	83.1	— 8.4	70.0	70.5	— 4.5

The azimuth and Δ are reproduced from p 45 of the Summary : the correction in the 4th column is from the above Table : Δ_p and Δ_s are the values of Δ corresponding to the P and S observations shewn on p 45 of the Summary; the mean of them is taken as the observed value O, from which the corrected calculated value is subtracted. The values of O — C for Zi-ka-wei, Taihoku, and Manila are closely consistent : those for Batavia and Riverview are discordant in opposite directions. The mean value for the group is + 1°.2 with them and + 1°.3 without them.

Group II (*Japanese*)

Station	Az	Δ	Corr	Δ_p	Δ_s	O — C
Kobe	97°	20°.6	— 2°.9	9°.7	—	— 8°.0
Osaka	97	20.8	— 2.9	9.9	—	— 8 .0
Nagoya	94	21.8	— 3.1	9.3	—	— 9 .4
Tokyo	91	23.8	— 3.3	10.1	9°.8	— 10 .5
Mizusawa	82	23.9	— 3.4	13.2	11 .1	— 8 .4

The mean azimuth is here 92° and the mean of 5 consistent values of O — C is — 8°.9, indicating that the epicentre should be about 9° further East.

Group III (*Indian*)

Station	Az	Δ	Corr.	Δ_p	Δ_s	O — C
Calcutta	233°	25°.3	— 3°.6	33°.2	33°.6	+ 11°.7
Simla	262	27.9	— 4.0	31.9	29.6	+ 9.3
Bombay	248	38.3	— 5.2	47.8	—	+ 14.7

The mean of three rather discordant values for azimuth 248° is + 11°.7, again requiring an eastward displacement.

GROUP IV (*European*)

Station	Az	Δ	Corr.	Δ_p	Δ_s	O — C
Lemberg	311°	58°.3	— 6°.9	60°.3	59°.9	+ 8°.7
Zagreb..........	310	64.9	— 7.3	65.5	65.7	+ 8.0
Pola............	310	66.7	— 7.4	66.2	67.2	+ 7.4
De Bilt.........	320	67.3	— 7.4	66.0	65.8	+ 6.0
Dyce............	327	67.5	— 7.5	65.3	65.2	+ 5.2
Zurich..........	314	68.3	— 7.5	67.5	67.8	+ 6.8
Uccle...........	319	68.4	— 7.5	66.7	66.6	+ 5.8
Milan	312	69.0	— 7.5	69.6	68.4	+ 7.5
Eskdalemuir.....	326	69.1	— 7.5	65.8	71.1	+ 6.8
Rocca di Papa...	308	69.2	— 7.6	69.2	—	+ 7.6
Moncalieri......	313	70.2	— 7.6	68.9	69.4	+ 6.6
Paris...........	318	70.6	— 7.6	68.9	68.8	+ 5.8
Algiers.........	308	78.1	— 8.2	76.4	75.0	+ 5.8

The mean of 13 consistent values in mean azimuth 315° is + 6°8.

22. Collecting the results and equating the O — C to x sin Az + y Cos Az, we have

Mean Az	O — C	x sin Az + y cos Az	
150°	+ 1°.3	$= + .50\,x - .87\,y$	$= -$ 1°.5
92	— 8.9	$= + 1.00\,x - .03\,y$	$= -$ 9.9
248	+ 11.7	$= - .93\,x - .37\,y$	$= +$ 10.8
315	+ 6.8	$= - .71\,x + .71\,y$	$= +$ 4.3

It is clearly useless to attempt anything but an approximate solution when x and y are so large. The values $x = -10°.0$ and $y = -4°0$ give the numbers in the last column, which resemble O — C closely enough for a new attempt to be made, with epicentre

$40° + 4° = 44°$ N and $110° + 10° \sec 40° = 123°$ E say.

23. Ultimately the position 44°0 N, 131°0 E was adopted, and satisfies the observations fairly well, as will presently be shown. But first let us see what would happen if we tried to solve the equations for change of epi-

centre *without* any allowance for depth of focus. The equations would be

	(a)	(b)	Group
$+ .50\,x - .87\,y = +$	$1^\circ.3$	$- 2^\circ.6$ (or $- 4^\circ.5$)	I
$+ 1.00\,x - .03\,y = -$	8.9	$- 3.1$	II
$- .93\,x - .37\,y = +$	11.7	$- 4.3$	III
$- .71\,x + .71\,y = +$	6.8	$- 7.5$	IV

24. Under heading (a) are given the figures already used, which embody the correction for focus : under (b) are given the figures which reverse this correction. Since the correction depends on Δ, which varies largely in the doubtful Group I, (b) for group I will be $- 2^\circ.6$ if we exclude Batavia and Riverview, and $- 4^\circ.5$ if we include them : we select the former, as the latter only accentuates the difficulty to be mentioned. The difficulty is most clearly seen by regarding the solution as the sum of two separate solutions, one with (a) alone, (which has already been presented) and one with (b) alone.

25. Confining attention to the (b) terms compare the equation II with III reversed in sign. viz :

$$+ 1.00\,x - .03\,y = - 3^\circ.1$$
$$+ 0.93\,x + .37\,y = + 4.3$$

Unless y is very large compared with x, these equations are incompatible. The actual solution is approximately

$$x = - 2^\circ.5 \qquad y = + 18^\circ.$$

Again compare IV reversed with I

$$+ .50\,x - .87\,y = - 2.6$$
$$+ .71\,x - .71\,y = + 7.5.$$

The solution of these is $x = + 32^\circ$ $y = + 21^\circ$.

The equations in fact will not give a reasonable solution . They represent the geometrical necessity of moving the epicentre opposite ways, stations in every azimuth requiring it nearer to themselves. The only way to satisfy this requirement is to move the focus downwards into the earth, when it approaches all stations except those near the epicentre.

26. Returning now to the solution for the [a] terms, we have to shew how far the solution adopted, viz 44° o N 131° o E satisfies the observations. Altering the epicentre by a large quantity like 10° of course alters all the corrections for focus ; and it is unprofitable to follow the solution through its tentative stages . The final solution for the various groups stands thus :

Group I (*with adopted Epicentre*)

Station	Az	Δ	Corr.	Δ_p	Δ_s	O — C
Zi-ka-wei	214°	14°.9	— 1°.9	13°.1	12°.2	— 0°.3
Taikohu	205	20.5	— 2.9	16.8	—	— 0.8
Manila	198	30.6	— 4.4	24.7	24.5	— 1.6
Batavia	210	54.7	— 6.7	46.4	46.4	— 1.6
Riverview	164	80.0	— 8.3	70.0	70.5	— 1.4
Mean	198					— 1.1

It will be seen that the results for Batavia and Riverview are now in fair accord.

Group II (*with adopted Epicentre*)

Station	Az	Δ	Corr	Δ_p	Δ_s	O — C
Kobe	160°	9°.9	— 0°.8	9°.7	—	+ 0°.6
Osaka	158	9.9	— 0.8	9.9	—	+ 0.8
Nagoya	151	9.9	— 0.8	9.3	—	+ 0.2
Tokyo	138	10.7	— 1.0	10.1	9.8	+ 0.3
Mizusawa	119	9.0	— 0.6	13.2	11.1	(+ 3.6)
Mizusawa corrected 1 min	119	9.0	— 0.6	9.0	8.8	(— 0.5)
Mean	152					+ 0.5

The readings for Mizusawa seem to be 1 min. too large. The effect of this correction is shewn in the second line but it seems better to exclude the station in taking the mean.

Group III (*with adopted Epicentre*)

Station	Az	Δ	Corr	Δ_p	Δ_s	O — C
Calcutta.........	255°	41°.0	— 5°.5	33°.2	33°.6	— 2°.1
Simla...........	272	43.7	— 5.8	31.9	29.6	— 7.2
Bombay.........	263	54.3	— 6.6	47.8	—	+ 0.1
Mean..........	263					— 3.1

Group IV (*with adopted Epicentre*)

Station	Az	Δ	Corr	Δ_p	Δ_s	O — C
Lemberg.........	318°	66°.7	— 7°.5	60°.3	59°.9	+ 0.9
Zagreb..........	319	73.4	— 7.9	65.5	65.7	+ 0.1
Pola............	320	75.1	— 8.0	66.2	67.2	— 0.4
De Bilt..........	328	73.2	— 7.9	66.0	65.8	+ 0.6
Dyce............	337	71.5	— 7.8	65.3	65.2	+ 1.5
Zurich...........	323	75.6	— 8.0	67.5	67.8	0.0
Uccle............	328	74.5	— 8.0	66.7	66.6	+ 0.1
Milan............	322	76.7	— 8.0	69.6	68.4	+ 0.3
Eskdalemuir......	334	73.4	— 7.9	65.8	(71.1)	+ 0.3
Rocca di Papa...	319	78.0	— 8.1	69.2	—	— 0.7
Moncalieri.......	323	77.8	— 8.1	68.9	69.4	— 0.5
Paris............	328	76.8	— 8.0	68.9	68.8	0.0
Algiers..........	320	86.5	— 8.4	76.4	75.0	— 2.4
Mean..........	325		—			0.0

27. For improvement of this adopted position we should accordingly have the equations

Az	O — C	x sin Az + y cos Az
198	— 1°.1	$= - .31x - .95y$
152	+ 0.5	$= + .47x - .88y$
263	— 3.1	$= - .99x - .12y$
325	0.0	$= - .57x + .82y$

It thus appears that the adopted solution is capable of improvement.

28. The supposition $x = +1^\circ.4$ $y = +1^\circ.0$ gives residuals

$$+0^\circ.3 \quad +0^\circ.7 \quad -1^\circ.0 \quad 0^\circ.0$$

to the four equations. The weakest group (and the most discordant) is Group III : and this is largely due to the discordance of Simla. If we exclude Simla the O — C for Group III becomes — 1°.0, and then the solution

$$x = +1^\circ.0 \quad y = +0^\circ.7$$

gives residuals — 0°.1, + 0°.6, + 0°.1, 0°.0. Or giving Simla halfweight, we have

$$x = +1^\circ.2 \quad y = +0^\circ.8$$

with residuals 0°.0 + 0°.6 — 0°.6 0°.0.
The revised position 43°. 2 N 129°. 3 E would thus seem to be an improvement.

29. One further point may be noticed. How far does the position of the epicentre depend on the assumed depth of focus ? If we increase the assumed depth, we get a new set of corrections which will be all larger than before, and thus we shall introduce into the constant terms of the equations quantities all of the same sign. We have already seen the difficulties arising from such an introduction in § 25 : but we may again consider them in detail.

30. Let us alter the assumed depth to .060 instead of .070, the equations of § 27 become (with half weight for Simla)

$$\begin{aligned}
-.31x - .95y &= -1^\circ.1 - 0^\circ.6 = -1^\circ.7 \\
+.47x - .88y &= +0.5 - 0.1 = +0.4 \\
-.99x - .12y &= -1.9 - 0.8 = -2.7 \\
-.57x + .82y &= 0.0 - 1.0 = -1.0
\end{aligned}$$

31. We can either solve these direct, or for the additional terms only : the latter course gives us the simplest

indication of the *change*. The values $x = + 1^{o}.0$, $y = + 0^{o}.09$ (obtained by making the coefficients of x all the same sign, and then the coefficients of y) give as residuals $- 0^{o}.2 - 0^{o}.5, + 0^{o}.2 - 0^{o}.5$; i. e. the large group IV (European group) is much disturbed. To obviate this we might give it more weight : and as an extreme case let us satisfy it exactly by putting

$$y = - 1^{o}.2 + .70\,x.$$

Substituting in the other equations, we find $x = + 1^{o}.7$ $+ 8^{o}.0$, $+ 0^{o}.8$ respectively : which leaves us a wide choice. We may try several hypotheses as below :

x	y	Residuals			
$+ 1^{o}.0$	$- 0^{o}.5$	$- 0^{o}.8$	$- 1^{o}.0$	$+ 0^{o}.1$	$0^{o}.0$
$+ 2.0$	$+ 0.2$	$+ 0.2$	$- 0.9$	$+ 1.2$	0.0
$+ 3.0$	$+ 0.9$	$+ 1.2$	$- 0.7$	$+ 2.3$	0.0

32. Now though none of these commends itself as an improvement on zero residuals, we do not as a fact start with zero residuals, but with the set $0^{o}.0, + 0^{o}.6 - 0^{o}.6, 0^{o}0$ (see § 28). The positive residual for Group II could thus be mitigated by addition of one of the above sets. But they are too large : we should do better to assume a smaller change of focal depth from .070, say to .065 instead of to .060. We must then halve the values of x, y, and the above residuals, of which the first set will suit us best : *ie.*

$$x = + 0^{o}.5, \qquad y = - 0^{o}.2.$$

The final solution would thus be focal depth 0.065 :

$$x = + 1^{o}.2 + 0^{o}.5 = + 1^{o}.1$$
$$y = + 0.8 - 0.2 = + 0.6$$

New epicentre $43^{o}.4$N $128^{o}.6$ E.

$$A = - .461 \qquad B = + .577 \qquad C = + .687$$

Equations				Residuals
$-.31x - .95y =$	$-1^\circ.1$	$-0^\circ.3$	$= -1^\circ.4$	$-0^\circ.3$
$+.47x - .88y =$	$+0.5$	$+0.1$	$= +0.4$	$+0.1$
$-.99x - .12y =$	-1.9	-0.4	$= -2.2$	-0.4
$-.57x + .82y =$	0.0	-0.5	$= -0.5$	0.0

33. The individual members of the groups do not differ much among themselves in either azimuth or Δ, except in the case of Group I, for which the revised figures are as follows (replacing those in § 26) :

GROUP I

With focal depth 0.065 *and Epicentre* 43°.4 N 128°6 E

	Δ	Corr.	Δ_p	Δ_s	O — C	Formerly
Zi-ka-wei........	13°.1	— 1°.3	13°.1	12°.2	+ 0°.9	— 0°.3
Taikohu.........	18.9	— 2.3	16.8	—	+ 0.2	— 0.8
Manila	29.2	— 4.0	24.7	24.5	— 0.6	— 1.6
Batavia	53.2	— 6.2	46.4	46.4	— 0.6	— 1 6
Riverview	79.9	— 7.7	70.0	70.5	— 2.0	— 1.4
Mean					— 0.4	— 1.1

The reduction of the mean residual for the group has thus been attained at the expense of accordance within the group; for on subtracting the mean value, the numerical sum of the new remainders is ± 3°.9, whereas formerly it was only ± 2°.4. Hence it is not altogether clear that the last change is for the better.

34. This example has been worked out in full detail in preference to dwelling on any theoretical discussion. Those who are doubtful about the assumption of deep focus will probably learn much more about its merits and demerits by numerical study of the cases given in §§ 8 and 9 than in any other way. Can they suggest any satisfactory alternative method of dealing with such cases ?

Effect of depth of focus on reflected rays.

35. We now turn to another consequence of the assumption of deep focus, viz its effect on the reflected rays, and especially on PR_1. Assuming that the adopted tables are correct, and that the focus is close to the earth's surface, the time for P when $\Delta = 60^\circ$ is 10 m 12 s, and for PR_1 is 2×6 m 28 s = 12 m 56s, following P by 2 m 44 s.

36. But now suppose that the focus is 0.060 below the surface. Knott's results for $\varphi = 24^\circ\ 18'$ in § 16 shew us that whereas the whole arc of $65^\circ\ 32'$ is described in 645 s.2, if we start from the depth 0.06 ($r = 0.94$) we have an arc $65^\circ\ 32' - 1^\circ\ 55' = 63^\circ\ 37'$ described in 645s.2 — 54s.2 = 591s.0. Knott only calculates a few special cases, so that we must fill in the gaps by some artifice ; and comparison with the tables is an easy method. For $63^\circ.6$ the tables give 636 sec so that the correction for deep focus is — 45 sec. By using Knott's values for $\varphi = 24^\circ\ 38'$ we find similarly that the correction for $55^\circ\ 43'$ is — 43 sec ; so that for $60^\circ.0$ we may take — 44 sec as sufficiently accurate; i. e. the time for P at $60^\circ 0$ is 612 — 44 = 568 sec.

37. Again the table for $\varphi = 42^\circ\ 32'$ shews us that a ray starting from $r = 0.94$ describes an arc $26^\circ\ 29' - 4^\circ\ 35'$ (or $21^\circ\ 54'$) in 352 — 77.8 (= 274.2 s). It will then be reflected at the surface and describe the complete arc $26^\circ\ 29'$ in 352.0 sec so that an arc $21^\circ.\ 54' + 26^\circ\ 29' = 48^\circ\ 23'$ is described in 274.4 s + 352.0 s in PR_1 fashion. The tables would give (on the ordinary assumption of 2 arcs of $24^\circ.2$) a time 2×330s = 660s : so that PR_1 falls short by 33.8s owing to focal depth 0.06.

Similarly from the table for $\varphi = 30^\circ\ 18'$ we find that arcs of $38^\circ\ 25' + 40^\circ\ 57' = 79^\circ\ 22'$ are described in PR_1 fashion in 422s.1 + 480s. 8 = 902s.9 whereas two arcs of $39^\circ\ 41'$ require 944s; a difference of 41s. By interpolation we gather that the assumption of a focal depth .06 reduces the apparent time for PR_1 at $\Delta = 60^o$ by 37s : and for P, as found above, by 44s : so that the change in the interval by which PR_1 follows P is only 7 sec, considered in this way, being increased from 2^m 44s to 2^m 51s ; for focal depth 0.04 it would be less still, say 5 sec.

Correction of tables

37. But this calculation is based on the erroneous assumption that the adopted tables apply to a focus close to the surface. If, as argued in § 8, the normal focus is at a depth 0.040 (approximately) below the surface, then the tables require considerable modification to be applicable to a surface focus, (as explained already in the *International Summary* for 1920 Jan. Feb. March p. 3). Denoting the epicentre by E (Fig 1) the focus 0.040 below it by N, and an observing station 10^o distant from E by B, then the present tables give the time when P is observed at E as T_0, at B as $T_0 + 150$ sec, where T_0 is the actual moment of the shock.

38. But suppose the focus were at D 040, lower down still (.080 altogether) : it has been shewn in § 18 that the existing tables can be used if we apply to E B the correction $- 0^o.5$, and at the epicentre itself the correction $+ 1^o.5$, making the effective $\Delta + 9^o.5$ for B and $+ 1^o5$ for E ; and the tables now give the times as $T_0 + 23$s. and $T_0 + 143$ ' the interval falling from 150 to 120s. If then we take a focus .040 *higher* than N (so as to be at E in the surface) instead of *lower*, we must reverse this process (as a crude first approximation). The effective distances become $+ 10^o.5$ and $- 1^o.5$; the times $T_0 + 157$s and $T_0 - 23$s ; and the interval 180s. Extending this procedure to other values of Δ, the effect of raising the

focus by .040 may be expressed in tabular form as follows :

Δ from Epicentre	0°	5°	10°	20°	30°	60°	90°
Effective Δ........	— 1.5	+ 4.9	10.5	21.6	32.6	64.6	95.4
P from tables.....	— 23s	+ 76s	157s	300s	413s	642s	825s
23 s added........	0	99	180	323	436	665	848
Present tables	0	77	150	281	388	612	795
Diff	0	22	30	42	48	53	53

39. It will be seen that a correction of about 53s. is ultimately needed for P near 90°, but that nearly half of this accrues in the first 5°. The time for describing the first 5° is increased from 77 to 99s, so that the adopted surface velocity must be considerably decreased.

40. But this removes a recognized difficulty. The Oppau explosion shewed that the surface velocity is much smaller than that adopted in the Tables. Jeffreys and Wrinch found it to be 5.4 km/sec as against 7.1 km/sec adopted in the tables, which is a decrease in the ratio 0.76. We are now proposing a decrease in the ratio 77/99 = 0.78, which is at least of the right order of magnitude, and suggests that the depth 0.04 for the normal focus cannot be grossly in error.

41. But this general increase in the times of the adopted tables has a direct effect on the intervals PR_1 — P and similar intervals between a reflected and direct wave : for the general increase occurs *singly* in P and *doubly* in PR_1. For instance the P wave for Δ = 60° is increased by 53 sec but the PR_1 wave by 2 × 48s = 96s (since the P wave for 30° is increased by 48s) ; so that the interval PR_1 — P is increased by 96s — 53s = 43s, a much larger quantity than the 5s formerly found and in the same direction, making the total increase 48s. When Δ is greater still, the increase is greater still. And this again

is in accordance with observation. On tabulating the results for PR_1 for 37 well determined Earthquakes between 1917 May and 1919 Jan 1 (taken from the Seismological Bulletins and Summaries), Mr. J.S. Hughes found that betwen $\Delta = 120^0$ and $\Delta = 140^0$ the records of (PR_1 — T_0) could be represented in the mean by

$PR_1 - T_0$ in minutes $= (9.5 + \Delta/10)$ in degrees whereas the tables give approximately the value $(8.6 + \Delta/10)$ in degrees. These formulae would give

Δ	(9.5 + Δ/10)	(8.6 + Δ/10)	Tables
120°	21.5	20.6	20.4
130°	22.5	21.6	21.5
140°	23.5	22.6	22.6

The observed values thus shew an excess of 0.9 m = 54s. over the tables in accordance with the above arguments.

42. But it must be frankly stated that this is only true in the mean of a large number of observations, and that in many instances PR_1 seems to come at the tabular time even at great values of Δ. Mr. Hughes's diagram gives the impression of a double phenomenon, or perhaps a variable phenomenon, of which further investigation is needed. But the mean result is pretty clearly as above.

43. The chief points in this paper may now be collected as follows :

(*a*) A formula and table are given for the arrival of the first disturbance [P] at stations near the antipodes of the epicentre (§§ 2 — 4). But certain earthquakes shew systematic deviations from this table or formula (§ 5).

(*b*) This systematic difference denotes that the focus is lower or higher than usual. A list of such cases is given. The hypothesis involves the assumption of about 0.04 earth's radius for the depth of the normal focus, in order to leave room above it for observed deviations in that direction. (§§ 6 — 10).

(*c*) Stations near the epicentre will also be affected. Close to the epicentre P and S will arrive later, but at most stations earlier, when the focus is deeper than usual : and vice versâ. This is easily seen *qualitatively* (§§ 11 — 14).

(*d*) To test it quantitatively use is made of Prof. C.G. Knott's work on the P and S rays (Proc R. S. E. 39, part ii N° 14). Some of his results are reproduced here. From them we deduce the virtual displacement of the station towards or from the epicentre, for different focal depths (§§ 15-18).

(*e*) The use of the table is explained and an example fully worked out, shewing how the focal depth deduced from the stations near the antipodes may be used to bring other stations into accord; whereas without that assumption they would be discordant (§§ 19-33).

(*f*) The effect of deep focus on PR_1 and other reflected rays. The chief effect comes through the alteration of the tables necessary to make fit a surface focus, as they are (erroneously) presumed to do at present. The times for P and S require an increase which ultimately mounts to 53s for P (and 95s for S), nearly half of these increases accruing in the first 5° from the epicentre. The surface velocities are thus brought into accord with those deduced from the Oppau explosion, which are quite discordant from the present tables. The observations of PR_1 are also satisfied by this change *on the average*, though further investigation is needed here (§§ 34-42).

(*g*) Finally it will be seen from the above argument that though the present tables are undoubtedly in error and require revision, that revision cannot be profitably undertaken until the above matters are fully investigated. At present the discussion is only provisional and imperfect.

The present tables serve their purpose well, and are better than others suggested to replace them. This will be made clear in the discussion of the large Kansu earthquake of 1920, Dec. 16, which will appear in the number of the Bulletin just going to press. For these reasons I think the best plan is to retain them in use until thoroughly revised tables can be prepared.

University Observatory, Oxford.

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Sur la nature de l'onde initiale des téléséismes enregistrés à Uccle de 1910 à 1924

Par O. SOMVILLE

C'est en 1909 que Galitzine (1) a, le premier, attiré l'attention sur la possibilité de déterminer la position géographique approchée d'un épicentre à l'aide des données d'une seule station. Il faut disposer pour cela d'un pendule vertical très sensible et de deux pendules horizontaux convenables, tels que ceux qui portent actuellement son nom.

Cette détermination se fait habituellement par l'étude des premières déviations des instruments. Le pendule vertical permet d'abord de se rendre compte si le premier déplacement du sol a eu lieu vers le bas, c'est-à-dire vers le foyer, ou bien vers le haut, c'est-à-dire dans une direction opposée au foyer ; en un mot, il nous fixe sur la nature de l'onde initiale : onde de dilatation dans le premier cas, onde de compression ou de condensation dans le second. Les déviations des pendules horizontaux permettent ensuite de déterminer la direction du plan de pro-

(1) Galitzin (Fürst B). *Zur Frage der Bestimmung des Azimuts des Epizentrums eines Bebens.* Bulletin de l'Académie Impériale des Sciences de Saint-Pétersbourg, n° 14, 1909.

pagation de cette onde, lequel est défini par la direction du déplacement du sol à la station et le centre de la terre ; normalement, ce plan passe par le foyer. Si en plus de ces données, on connaît la distance qui sépare la station de l'épicentre, distance qui se calcule d'après la différence de temps d'arrivée des ondes longitudinales et transversales, on a alors tous les éléments nécessaires pour calculer la position géographique de cet épicentre.

Pour déterminer la nature de l'onde initiale d'un téléséisme, connaissant *a priori* la position du foyer, il n'est pas nécessaire de recourir au pendule vertical ; les déviations de deux pendules horizontaux installés perpendiculairement l'un à l'autre suffisent pour faire cette détermination sans aucune ambiguité ; même si les types d'instruments dont on dispose donnent peu de précision au point de vue du calcul des azimuts.

Après quinze années d'enregistrement des tremblements de terre du monde entier avec les meilleurs appareils [1], il nous a paru intéressant de dresser la liste de tous les téléséismes qui ont débuté à Uccle par une onde très nette dont la nature pouvait être déterminée avec certitude. Cette liste se trouve reproduite ci-dessous. Les téléséismes y sont groupés par régions épicentrales. Outre l'heure du début à Uccle et les coordonnées de l'épicentre calculées d'après les meilleures observations publiées, elle contient encore des indications symboliques sur le mode d'apparition de la première onde ; c'est-à-dire s'il s'agit d'un *e*P, d'un P ou d'un *i*P.

Nous nous permettons de signaler, en passant, que ces trois symboles, couramment utilisés dans les bulletins séismiques, nous paraissent absolument insuffisants pour dépeindre d'une façon précise les caractéristiques des premiers déplacements du sol. Ils pourraient suffire, à

[1] L'installation de notre pendule Wiechert de 1.000 kilogrammes date de septembre 1909 ; le pendule vertical, de septembre 1910 et les pendules Galitzine, d'avril 1911.

la rigueur, à la condition d'indiquer aussi dans les bulletins l'amplitude (même en valeur relative) des déviations qu'ils caractérisent.

Alaska et Iles Aléoutiennes

1	1912	4 I	15h58m54s	52° N	179° E	*i*P	cond.
2		8 VII	22 04 24	63	143 W	*i*P	cond.
3		7 XI	7 51 31	57	155 W	*i*P	cond.
4	1913	30 IV	11 46 35	52	174 W	*i*P	cond.
5	1917	25 VII	22 44 33	54	159 W	*i*P	cond.
6	1922	2 IV	19 29 34	54	166 W	*e*P	cond.
7		2 VII	13 47 33	53,5	157,5 W	P	cond.
8	1923	3 II	16 13 15	50	168 E	P, *i*P	cond.
9		4 V	16 38 10	55	159 W	P	cond.
10		22 VII	14 29 54	52	174 E	*e*P	cond.

Kamtschatka — Iles Kouriles — Mer d'Ochotsk
Est sibérien — Nord du Japon

(au-dessus du 40e degré)

11	1911	4 V	23h48m20s	53° N	152° E	*i*P	dilat.
12	1913	19 I	23 59 49	49	147	*i*P	dilat
13		20 II	9 11 14	43	141	*i*P	cond.
14		1 VIII	17 23 03	47	153	*i*P	dilat
15	1915	17 III	18 56 58	43	138	*i*P	cond.
16		1 V	5 12 02	48	158	*e*P, *i*P	cond. (*e*P douteux)
17		6 VIII	13 24 39	45	152	P	dilat.
18	1916	31 X	15 42 48	48	160	P	cond.
19	1918	30 I	21 29 44	45	135	*i*P	dilat.
20		10 IV	2 14 40	44	131	*i*P	dilat.
21		7 IX	17 28 24	46	151	P	cond.
22	1919	3 V	1 04 26	41	146	P	dilat.
23	1920	18 X	8 23 41	47	150	*i*P	cond.
24	1921	2 I	7 18 47	43	148	P	dilat.
25	1922	4 III	13 18 53	54	148	P	dilat.
26		16 VIII	16 08 05	52	155	P	cond.
27		24 X	21 33 01	48	149	*i*P	dilat.
28		31 XII	7 32 13	45	149	*e*P	cond.
29	1923	24 II	7 46 11	53	154	*i*P	dilat
30		23 V	22 48 44	52	163	*e*P	cond.
31	1924	30 VI	15 56 14	46,5	141,5	*i*P	dilat.

Japon — Formose

32	1911	15 VI	14h38m20s	28° N	129° E	*e*P, *i*P	cond. (*e*P douteux)
33	1914	6 VII	6 50 14	24	122	*i*P	cond.
34	1915	1 XI	7 36 18	39	142	*e*P, *i*P	cond.
35	1920	5 VI	4 34 20	24,5	124	*i*P	cond.
36	1921	3 III	3 14 51	37	141	P	cond.
37	1922	1 IX	19 28 51	24	122	*i*P	cond.
38	1923	1 VI	17 37 23	37	141	*e*P	cond.
39		1 VI	20 28 23	37	141	*e*P	cond.
40		13 VII	11 26 15	33	130	P	cond.
41		1 IX	3 11 09	35	139,5	P	cond.
42		2 IX	2 59 20	»	»	P	cond.
43		2 IX	9 39 32	»	»	*e*P	cond.
44		5 XI	21 40 38	31	129	*e*P	eond.
45	1924	14 VIII	18 15 14	36	142	P	cond.

Asie

46	1911	3 I	23h34m27s	43°,5 N	78°,5 E	*e*P, *i*P	cond.
47		4 VII	13 41 52	42	74	*i*P	cond.
48	1912	23 VIII	21 50 02	40,5	70,5	*i*P	cond.
49	1916	28 VIII	6 49 39	30	81	*i*P	cond.
50	1917	21 IV	0 58 09	37,5	70,5	P	cond.
51		15 VII	18 05 52	33,5	46,5	*i*P	cond.
52	1920	16 XII	12 16 54	36	105,5	*e*P, *i*P	cond. (*e*P, très faible dilat.)
53		25 XII	11 44 22	36	104	*i*P	cond.
54	1921	20 V	0 51 45	37	67	*i*P	cond.
55		15 XI	20 45 03	37	67	*i*P	cond.
56	1922	6 XII	14 04 00	38	73	*i*P	cond.
57	1923	22 VI	6 56 20	22,5	99,5	*e*P	cond.
58		9 IX	22 14 51	26	92,5	*e*P	cond.
59	1924	3 VII	4 49 52	37	86	P	cond.
60		11 VII	19 54 21	38	86	*e*P	cond.
61		12 VII	15 21 13	40	73	*e*P	cond.
62		13 X	16 26 11	40	70	*i*P	cond.

Océan Indien

63	1912	11 V	17h38m49s	6°5 S	70° E	*i*P	dilat.

Afrique

64	1910	13 XII	11h47m42s	9° S	34° E	*i*P	dilat.
65	1919	8 VII	21 16 42	7,5 S	36	*i*P	dilat.
66	1921	14 VIII	13 23 51	15,5 N	39,5	*e*P	dilat.

Régions de la Mer Méditerranée

67	1910	18 II	$5^h13^m49^s$	35°,5 N	23° E	*i*P	dilat.
68		24 VI	13 30 28	36	3,7	*i*P	dilat.
69		1 VIII	10 43 28	38,4	15,9	*i*P	dilat.
70	1911	4 IV	15 48 32	36	25	*i*P	dilat.
71	1912	24 I	16 27 17	38	20,6	*e*P, *i*P	dilat.
72		17 V	16 43 36	34,8	24,4	*i*P	dilat.
73		9 VIII	1 33 12	40,7	27,9	*e*P, *i*P	dilat.
74		10 VIII	9 28 11	40,6	27,5	*e*P, *i*P	dilat.
75		13 IX	23 35 43	40	26	*i*P	dilat.
76	1913	14 VI	9 37 08	42,2	26,3	*i*P	dilat.
77	1915	13 I	6 55 19	42	13,5	*i*P	cond.
78		27 I	1 13 44	38,4	20,7	P	cond.
79		7 VII	16 45 48	40	12,5	*i*P	dilat.
80		7 VIII	15 08 05	38	20,5	*i*P	dilat.
81	1916	26 I	7 41 28	46	25	*i*P	dilat.
82	1917	28 XII	16 07 33	40	12,5	*i*P	dilat.
83	1918	16 VII	20 08 29	36,3	26,3	*i*P	cond.
84	1919	18 XI	21 59 14	39,6	27,7	*i*P	dilat.
85	1920	7 IX	5 57 39	44	10,5	*e*P, *i*P	cond. (*e*P, faible dilat.)
86	1921	10 VIII	14 14 07	42,3	21,3	*e*P	cond.
87	1922	5 VI	4 35 50	34,5	23	*e*P	dilat.
88		8 VIII	3 53 34	37,6	23,4	*e*P, P	cond. (*e*P, faible dilat.)
89		11 VIII	8 24 12	34,5	30	*e*P	cond.
90		13 VIII	0 14 49	35	27	*e*P, *i*P	dilat. (*e*P, faible cond.)
91		4 XI	4 24 28	37,5	20	*e*P, P	dilat. (*e*P, faible cond.)
92		11 XI	22 17 25	38,2	22,5	P	cond.
93	1923	10 VII	5 33 21	42,6	0	*e*P	dilat.
94		5 XII	21 00 50	39	23,5	*e*P, *i*P	cond. (*e*P, faible dilat.)
95	1924	20 XI	20 32 41	38,7	30,5	P, *i*P	dilat. cond.

Océan Atlantique

96	1913	14 VI	$11^h37^m57^s$	59° N	34°,5 W	P	cond.
97	1914	3 X	17 32 29	13 N	57	*i*P	cond.
98	1915	11 VII	11 32 35	38 N	11	*i*P	cond.
99		18 XII	18 36 21	3 S	17	*i*P	cond.
100	1918	20 V	14 45 29	7,4 N	35,2	*i*P	cond.
101		3 VI	0 12 53	0,4 S	20	*i*P	cond.
102	1920	12 XI	5 51 46	2 S	23	P	cond.
103	1921	22 IV	16 07 43	43 N	17,5	*e*P	cond.
104	1922	9 I	5 18 06	19,5 N	40,5	P	cond.
105		4 IX	17 18 21	22,5 N	49	*e*P	cond.
106	1923	30 IX	1 25 46	49 N	30,5	*e*P, *i*P	cond. (*e*P, douteux)
107	1924	14 X	5 08 50	22 N	42	*i*P	cond.

Région de l'Islande

108	1910	22 I	$8^h52^m49^s$	65° N	20° W	*i*P	dilat.
109	1912	6 V	19^h04 05	63,5	19	*i*P	cond.
110	1913	26 VII	20 55 38	66,5	18,5	*i*P	cond.
111	1914	19 VI	0 11 14	63,5	25,5	P	cond.
112	1921	23 VIII	20 21 59	64,5	22	P	dilat.
113	1922	8 IV	20 47 16	70	20	*i*P	cond.
114	1923	10 X	7 16 12	70	14	*i*P	dilat.

Régions ouest de l'Amérique du Nord

115	1915	3 X	7h05m00s	37° N	115° W	eP, iP	dilat (eP ?)
116	1922	31 I	13 29 29	41	125,5	eP	dilat.
117	1923	22 I	9 16 23	41	123,5	eP	dilat

Mexique et Amérique centrale

118	1911	7 VI	11h15m21s	18° N	100° W	iP	cond.
119		16 XII	19 27 04	17	97	iP	cond.
120	1914	30 III	0 53 24	15	97	eP, iP	cond.
121		28 V	3 35 52	10	80	P	cond.
122		28 V	18 10 32	17	97	P	cond.
123	1915	28 XII	23 52 16	15	88,5	iP	cond.
124	1916	24 IV	8 14 22	10	82	iP	cond.
125	1921	4 II	8 34 57	17	95	iP	cond.
126		28 III	8 01 35	14	86	iP	cond.
127	1924	6 VII	14 30 54	10	81	P	cond.

Amérique du Sud

128	1916	30 VI	3h13m07s	0°,5 N	82° W	iP	cond.
129	1917	31 VIII	11 48 31	5 N	75	iP	dilat.
130	1921	18 XII	15 40 59	4,5 N	67	iP	dilat
131	1922	17 I	4 02 02	4 N	64	P, iP	dilat. cond.
132		28 III	4 11 10	17 S	65	P	dilat.
133		11 X	15 03 06	17 S	71	P	cond.
134		11 XI	4 46 35	27 S	71	P	cond.

Antilles

135	1917	27 VII	1h11m57s	19° N	68° W	iP	dilat.

Afin de rendre beaucoup plus apparents les résultats de cette statistique, nous avons fixé sur une mappemonde en projection de Mercator (voir la carte ci-jointe) les positions géographiques de tous les épicentres considérés. Les foyers ayant donné lieu à une condensation sont figurés sur la carte par des points noirs; tandis que les foyers correspondant à une dilatation sont représentés par des points rouges. Un point noir barré de rouge signifie que le séisme a donné lieu, à une faible dilatation suivie d'une condensation beaucoup plus saillante constituant le mouvement principal, et inversement pour un point rouge barré de noir.

La distribution des épicentres apparaît ainsi très frappante, attendu que les foyers qui donnent à Uccle des ondes de même nature, se groupent d'une façon systématique. On remarque, en premier lieu, que les séismes qui ont leur siège dans les massifs de l'Asie centrale, ont toujours débuté à Uccle par une onde de condensation. Il en est de même des tremblements de terre de l'Alaska, des Iles Aléoutiennes, de l'archipel japonais (en dessous du 40e degré de latitude Nord) y compris Formose, de l'Amérique centrale et de l'Océan Atlantique à l'exception de la région de l'Islande. Par contre, les séismes de quelques autres régions ont, pour la plupart, débuté par une onde de dilatation ; tels ceux qui se sont produits dans le voisinage des Iles Kouriles et de la mer d'Ochotsk où l'on remarque un amas important de points rouges ; ceux des régions de la Méditerranée, des lacs africains, de l'ouest de l'Amérique du Nord et des parties continentales de l'Amérique du Sud, alors que les séismes des parties côtières, du côté du Pacifique, donnent au contraire des condensations.

Dans ce qui précède, il est donc question de la nature ou de la direction du premier mouvement du sol en un même lieu pour un grand nombre de tremblements de terre appartenant aux diverses régions séismiques du globe. Au Japon, S. Nakamura [1] a, au contraire, étudié la direction du premier mouvement des tremblements de terre dans un certain nombre de stations japonaises entourant un même foyer. Les directions observées se répartissent d'une façon très systématique autour des

[1] S. Nakamura : *On the Direction of the First Movement of the Earthquake.* Journal of the meteorological Society of Japan, n° 2, February, 1922.

épicentres. Un type de distribution fréquemment observé est le suivant : les stations d'observations sont partagées en quatre secteurs limités par des lignes légèrement courbes. Dans deux secteurs opposés les premiers déplacements sont dirigés vers l'épicentre et dans les deux autres secteurs, en sens inverse. Un autre type observé est celui-ci : d'un côté d'une certaine ligne, toutes les stations indiquent des mouvements dirigés vers l'épicentre et de l'autre côté des mouvements rayonnant de l'épicentre vers l'extérieur. Le tremblement de terre du 2 septembre 1922 (temps local) dont le foyer se trouvait au NE de l'île Formose, mérite à ce point de vue une mention spéciale ; S. Nakamura (1) a observé que non seulement dans les observatoires de l'île Formose et des îles voisines les premiers déplacements du sol étaient dirigés vers l'épicentre, mais qu'il en était de même dans toutes les autres stations japonaises dont quelques-unes situées à plus de 2.000 kilomètres dans l'île Nippon et en Corée. On remarque de suite que les stations éloignées se trouvent toutes d'un même côté de l'épicentre ; il aurait été intéressant de connaître le sens des premiers mouvements dans les autres directions, vers l'île Haïnan, l'Annam et les îles Philippines par exemple. A Uccle, le premier déplacement était dirigé en sens inverse de l'épicentre (voir dans la liste le n° 37).

La comparaison de cartes semblables à la nôtre relatant les résultats obtenus dans les principaux observatoires du globe, aurait présenté, on ne peut en douter, un très vif intérêt. Malheureusement, nous n'avons pu faire de comparaisons qu'entre quelques stations et pour un nombre très limité de tremblements de terre. Signalons d'abord l'accord toujours parfait entre les observatoires de De Bilt et Uccle pour tous les cas examinés.

(1) S. Nakamura : *On the Destructive Earthquakes in Formosa on the 2nd and 15 th of september*, 1922. The seismological Bulletin of the central meteorological observatory of Japan. Vol. I, n° 2, december 1922.

La nature de l'onde initiale des téléséismes est toujours la même dans ces deux stations quelle que soit la direction de l'épicentre. Dans deux cas, où cet accord semblait ne pas exister, il a été reconnu, après vérification, qu'il s'agissait de cas douteux, principalement à cause de la présence de microséismes. Pour nos recherches entre stations plus distancées, nous avons spécialement puisé aux sources suivantes :

Galitzin ([1]) *Bestimmung der Lage des Epizentrums eines Bebens aus den Angaben einer einzelnen seismischen Station* ; les bulletins séismiques de Poulkova, Irkoutsk et Iékatérinburg, années 1912, 1913, et 1923 (en partie) ; le Bulletin provisoire du Bureau central de Strasbourg, année 1924. Les résultats obtenus sont consignés dans les tableaux ci-dessous.

Alaska — Japon

	Séisme	Uccle	Poulkova	Iékatérinburg	Irkoutsk	Strasbourg
Alaska	N° 2	*i*P cond.	*i*P cond.	—	—	—
Alaska	3	*i*P cond.	*e*P, *i*P cond.	—	*i*P cond.	—
Aléoutes	4	*i*P cond.	*i*P cond.	—	*i*P cond	—
Aléoutes	10	*e*P cond.	—	*i*P cond.	—	—
Kamtschatka	30	*e*P cond.	—	*i*P cond.	—	—
Mer d'Ochotsk	12	*i*P dilat.	*e*P, *i*P dilat.	—	*i*P dilat.	—
Kouriles	11	*i*P dilat.	dilat	—	—	—
Kouriles	14	*i*P dilat.	(*iP cond.*)	—	—	—
Sakhaline	31	*i*P dilat	—	—	—	P dilat.
Yesso	13	*i*P cond.	P cond.	—	*i*P cond.	—
Nippon	38	*e*P cond	—	*i*P cond.	—	—
Nippon	39	*e*P cond.	—	*i*P cond	—	
Nippon	45	P cond.	—	—	—	*i*P cond.
Sud Japon	40	P cond.	—	*i*P cond.	—	—

Asie centrale

	Uccle	Poulkova	Irkoutsk	Strasbourg	Tolède	Grenade
N° 46	*e*P, *i*P cond.	cond.	—	—	—	—
48	*i*P cond	*i*P cond	*i*P cond.	—	—	—
62	*i*P cond.	—	—	*i*P cond.	*i*P cond	*i*P cond.

([1]) Bulletin de l'Académie Impériale des Sciences de Saint-Pétersbourg, septembre 1911.

Océan Indien

	Uccle	Poulkova
N° 63	*i*P dilat.	*i*P dilat.

Océan Atlantique

	Uccle	Poulkova	Tolède	Grenade
N° 96	P cond.	P cond	—	—
107	*i*P cond.	—	P cond	*i*P cond.

Islande

	Uccle	Poulkova	Iékatérinburg	Eskdalemuir
N° 108	*i*P dilat.	(*P cond.*)	—	—
109	*i*P cond.	(*eP*, *iP dilat*)	—	—
110	*i*P cond.	*e*P, *i*P cond.	—	—
114	*i*P dilat.	—	(*iP cond*)	*i*P dilat.
113	*i*P cond.	—	—	*i*P cond.

Régions de la Méditerranée

	Uccle	Poulkova	Irkoutsk	Strasbourg
N° 67	*i*P dilat.	(*cond.*)	—	—
68	*i*P dilat	(*cond*)	—	—
70	*i*P dilat.	dilat	—	—
75	*i*P dilat.	(*iP cond.*)	(*iP cond.*)	—
76	*i*P dilat.	(*iP cond.*)	—	—
95	P, *i*P dilat. cond.	—	—	P dilat.

Mexique

	Uccle	Poulkova
N° 118	*i*P cond.	cond.

Dans le travail de Galitzine cité plus haut, l'auteur donne le caractère de l'onde initiale de 42 téléséismes enregistrés à Poulkova du 2 juillet 1909 au 8 juin 1911. De ces téléséismes, 18 seulement méritent d'être retenus ; les autres sont très peu importants. De ces 18 cas, 7 ont été pris en considération ; ce sont les nos 11, 46, 67, 68, 70, 108 et 118. Nous donnons ci-dessous la région épicentrale et la nature de la première onde des 11 téléséismes restants.

1909	7. VII	Asie centrale	cond.	
	20-21. X	Asie centrale	cond.	
	10. XI	Japon	cond.	
1910	12. IV	Formose	(*dilat.*)	à Uccle, cond. précédée d'une très faible dilat. ; début peu caractéristique.
	23. V	Japon	cond.	
	31. V	Amérique centrale	cond.	
	5. VIII	Californie	dilat.	
	9. IX	Iles Aléoutes	cond.	
1911	1. I	Turkestan	(*dilat*)	à Uccle, début peu caractéristique.
	18. II	Balkans	dilat.	
	7 VI	Kamtschatka	cond.	

Quoique les données que contiennent les tableaux comparatifs ci-dessus soient très insuffisantes, elles laissent néanmoins l'impression, nous semble-t-il, que les stations européennes enregistrent des ondes initiales de même nature pour tous les séismes à foyer très éloigné (exception faite donc des tremblements de terre des régions de la Méditerranée et de l'Islande) ; à la condition de ne prendre en considération que les téléséismes remarquables où l'on a la certitude d'avoir enregistré la première onde et où l'amplitude de celle-ci est assez marquante pour pouvoir en déterminer nettement la nature.

L'étude des premières ondes des téléséismes enregistrés à Uccle, étude à laquelle nous avons pu joindre quelques éléments se rapportant à d'autres observatoires, permet ainsi d'affirmer que pour la plupart des régions séismiques du globe, il y a manifestement continuité dans les effets produits par tous les tremblements de terre qui se succèdent durant une période de temps présumée très longue.

Nous croyons, en outre, que la connaissance de la direction et de l'amplitude du premier mouvement du sol en un grand nombre de stations proches et éloignées d'un épicentre, peut fournir des indications précieuses sur les phénomènes qui se sont produits à l'hypocentre même. Considérons, pour fixer les idées, un cas typique très simple : si l'on observe par exemple des ondes de dilatation dans toutes les stations voisines ou peu éloignées d'un épicentre, tandis que l'on enregistre des compressions dans toutes les stations éloignées, on en déduira que l'on a affaire à un simple effondrement. De même, on pourra déterminer s'il s'agit d'un phénomène d'explosion ou de contraction, du déplacement ou glissement d'un compartiment entier de la croûte ou plus généralement du jeu de plusieurs de ces immenses blocs. Dans ces derniers cas, il n'est pas impossible que l'on arrive à déterminer les directions ou les axes des déplacements principaux.

Pour terminer, nous exprimons le vœu que les premières déviations des séismographes soient étudiées très attentivement dans l'avenir et en conséquence que les bulletins séismiques futurs contiennent à ce sujet des indications nombreuses et sûres.

Reçu en Janvier 1925.

Révision des Séismogrammes de Strasbourg de 1920,

d'après les résultats de « l'International Summary »

QUESTIONS QU'ELLE SOULÈVE

Par E. ROTHÉ

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Secrétaire de la Section de Séismologie

La publication faite à Oxford par Monsieur Turner « The international Summary » se distingue des catalogues publiés antérieurement en ce qu'elle constitue une œuvre critique et par là même de grande utilité. La lecture des différences O-C entre les heures d'observations et celles que donne le calcul pour les phases P et S des tremblements de terre permet de se rendre immédiatement compte de la justesse ou de l'inexactitude des dépouillements effectués dans les diverses stations. Je me suis proposé de réviser, comme M. Turner l'a demandé à ses collègues, les séismogrammes de Strasbourg en tenant compte de ces différences et j'indiquerai ci-dessous les observations auxquelles ce travail m'a conduit *en admettant les épicentres indiqués dans le Summary.* J'ai été aidé dans ce travail par M^lle^ Y. Dammann, préparatrice de la chaire de physique du globe, qui a bien voulu prendre part à cette révision et a refait dans les cas douteux les calculs correspondants.

Au cours de l'année 1920 les appareils Wiechert ont seuls été en fonctionnement continu : c'est donc sur les documents Wiechert que ce travail a été exécuté. Je me propose de le reprendre pour une année récente pour laquelle nous disposerons de la belle documentation fournie par les instruments Galitzine.

On peut dire d'une manière générale que pour la plupart des tremblements de terre bien inscrits les différences sont nulles ou trop faibles pour qu'on puisse se livrer à une discussion utile. Je n'ai pas donc fait figurer dans la nomenclature ci-dessous les séismes pour lesquels les divergences sont d'un petit nombre de secondes (le plus souvent inférieur à 5 même pour les S). Je n'ai insisté que sur ceux qui donnent vraiment lieu à une divergence importante et me suis alors efforcé d'en rechercher le motif, soit dans une erreur d'interprétation, soit dans toute autre cause. Dans le cas où il existe des différences importantes et où il est impossible de faire subir de correction aux résultats du dépouillement, on se trouve en présence de deux alternatives.

Ou bien il y aurait lieu de modifier la position de l'épicentre, ou bien la divergence provient d'une véritable *anomalie* qui peut être d'un haut intérêt pour la connaissance du sous-sol et pour les progrès de la séismologie. On verra *que ce cas se présente pour quelques tremblements de terre éloignés pour lesquels les S arrivent avec des différences importantes sans correction possible.*

D'autre part *il y a des différences notables pour les tremblements de terre rapprochés comme ceux d'Italie, des Balkans ou de la Méditerranée.* Dans ce cas les épicentres sont connus et il sera sans doute possible de lever les doutes en utilisant les tables de A. Mohorovicic, tenant compte de la profondeur du foyer, qui constituent le troisième fascicule de cette publication.

Le lecteur est prié de se reporter d'une part au Summary, d'autre part à l'Annuaire de l'Institut de Physique du Globe de Strasbourg 1920, pour les détails relatifs aux séismes dont je ne rappelle ici que les données utiles à la discussion même. Pour chacun d'eux j'indique la date, l'heure origine, les coordonnées de l'épicentre (la région géographique). Pour les phases P et S j'indique comme dans le Summary la durée de trajet à partir de l'heure origine.

J'appelle l'attention sur le fait qu'il est essentiel de distinguer entre eP et e. Le premier symbole veut dire que les P ne sont pas nets, (emersio) mais qu'il s'agit bien des P ; e se rapporte à une émergence de nature souvent inconnue.

2 II $11^h22^m15^s$ 7,0 S 150,0 E **Nord-est de la Nouvelle Guinée.**

*e*P 19 m 4 s *d* = [— 9] ; le début n'est pas net, mais une avance est impossible ; la divergence doit provenir de l'application des formules.

S 31 m 2 s *d* = 77. *Il est impossible d'avancer autant les S.*

Les SR_1 sont particulièrement développées ; la réflexion a lieu dans la région de Mongolie au SW de l'Ordos.

7 II $11^h50^m30^s$ 56,8 N 33,6 W **Océan Atlantique, Sud** du Grœnland.

e 4 m 30 s *d* = — 77 Début très incertain, changement de feuille.

S 10 m 24 s *d* = + 4 Pas de modification.

10 II $22^h7^m10^s$ 19.0 N 68.0 W **Antilles.**

*e*P 10 m 44 s *d* = — 11 Début troublé par le mouvement microséismique.

*i*S 19 m 50 s *d* = + 6 On peut réduire cette différence à + 4.

20 II $0^h1^m30^s$ 42,0 N 46,0 E Sud Caucase.

e 6 m 30 s *d* = + 28 L'erreur s'explique par la faiblesse de l'inscription *e* ; l'interprétation du même jour o = 11 h 44 m 25 s est au contraire complètement correcte.

15 III $12^h5^m30^s$ 20,0 S 176,5 E Sud-ouest des îles Fidji.

e (P) 19 m 27 s *d* = [29] Application de la formule pour les grands distances ; le retard provient de la faiblesse du début. Pour les S il y a lieu de prendre garde aux confusions possibles avec les SR_1 souvent particulièrement développées pour les séismes de cette région.

22 III $20^h1^m43^s$ 17°,0 S 177,5 W Iles Fidji.

e (P) 19 m 25 s *d* = [— 28] Avance difficilement explicable si ce n'est par le trouble apporté par le mouvement microséïsmique

23 III $15^h21^m48^s$ 14,5 N 91,0 W Guatemala.

P 12 m 38 s *d* = — 9 *e*S 22 m 57 s *d* = — 21 *Des avances du même ordre s'observent à Uccle, Hambourg, Strasbourg.* Les heures publiées ne peuvent être modifiées ?

29 III $5^h7^m40^s$ 50,5 N 129,5 W Ile Vancouver.

*e*P 11 m 50 s *d* = + 5
*e*S 21 m 30 s *d* = + 11 On peut mieux identifier les S et réduire cette différence à + 2

30 III $1^h4^m15^s$ 46,0 N 9,0 E Italie.

P 0 m 38 s *d* = — 4 S 1.m 35 s *d* = + 21 Il y aurait lieu d'étudier plus à fond ce séisme *en tenant compte de la profondeur du foyer* et en utilisant les tables Mohorovicic.

1 V 6h34m40s 37,0 N 28,7 E Asie mineure.

P 4 m 31 s $d = + 1$ On a indiqué une émergence *e* pour 7 m 7 s, mais non des S ; la différence — 57 ne leur correspond pas.

5 V 14h41m55s 45,5 N 15,0 E Côtes Adriatique, Frioul.

P 1 m 27 s $d = - 3$ *e*S 2 m 17 d = — 22 Les S ont bien été placées au bon endroit. Avance de cause analogue : il y a sans doute lieu de tenir compte de *la profondeur du foyer.*

7 V 5h40m40s 6,5 N 126,0 E Voisinage de Mindanao.

*e*P 14 m 39 s $d = + 17$ Retard explicable par la faiblesse de l'inscription au début.

7 V 21h31m10s 8°,4 S 155,8 E Iles Salomon.

*e*P 19 m 22 s $d = [0]$. La formule pour les grandes distances s'applique donc en toute rigueur. Les S qui ne figuraient pas dans l'annuaire peuvent se placer 32 m 11 s après le début ; les SR_1 sont très nettes à 39 m 20 s. Nombreuses séries de maximum.

10 V 18h49m40s 5°,5 130°,0 E Nord-est Célèbes

e 19 m 14 s C'est une émergence en retard qui fait partie des P. Ce ne sont pas les PR_1 ; *e*S $d = + 87$. Un retard important se manifeste par rapport aux S. *Anomalie* ?

12 V 21h53m12s 38,0 N 136,0 E Côtes Japon.

*e*P 12 m 26 s $d = - 4$ *e*S 22 m 36 $d = - 10$ Aucune correction apparente sur ces avances ?

13 V 1h48m25s 4,0 S 144,5 E Nouvelle Guinée.

e 20 m 34 s L'émergence marquée *e* ne correspond pas au début. Les PR_1 sont nets à 21 m 2. Le calcul donnerait 20 m 40 s. *e*S 30 m 4 s $d = + 95$ Il est impossible de placer les S à l'heure que le calcul assignerait. *Il semble qu'il y ait comme dans plusieurs autres cas signalés retard dans l'apparition des S.*

13 V $4^h40^m40^s$ 49,8 N 12,0 E Alpes Région Bohême.

*e*P 1 m 48 s Cette émergence ne devrait pas être désignée par P. Erreur d'interprétation. Pour les tremblements rapprochés faibles les L apparaissent seules.

20 V $7^h25^m55^s$ 11,7 S 166,3 E Iles Santa Cruz.

*e*P 19 m 25 s d = [— 13] Rien à modifier ; on observe les PR_1 après 22 m 29 s.

25 V $11^h39^m55^s$ 33,5 N 46,5 E Perse, Lauristan.

e 12 m 26 s Ce ne sont pas les P, qui n'apparaissent pas ; mais plutôt les S avec un retard *d* = + 12 s, tandis que les stations voisines accusent une avance du même ordre. Les divergences doivent tenir à la difficulté d'interprétation des tremblements de cette région. Les stations proches ne semblent pas avoir non plus de phases nettes.

5 VI $4^h21^m30^s$ 24,0 N 120,0 E Formose.

*i*P 12 m 46 s *d* = — 6 S 23 m 10 s d = — 17 Il n'est possible de rien modifier dans les observations. Les inscriptions sont très nettes. *Les avances s'expliqueraient-elles par une anomalie ou par la profondeur du foyer ?*

24 VI $5^h48^m45^s$ 64,1 N 27,5 W Océan Atlantique.

*e*P 4m 47 s *d* = — 45 Un faible mouvement a été inscrit sur le vertical ; il y aurait lieu de rechercher s'il existe sur d'autres appareils verticaux dans d'autres stations. C'est une avance incompatible avec les données des stations voisines ; c'est peut-être un petit mouvement indépendant du phénomène principal.

25 VI 18h21m45s 64.1 N 27,5 W Océan Atlantique.

*e*P 5 m 35 s *d* = + 3 *e*S 9 m 15 s *d* = — 37 Toutes les stations indiquent une avance pour les S. Celle de Strasbourg est la plus grande. *Anomalie à étudier.*

2 VII 18h41m5s 7,0 S 153.0 E **Région îles Salomon.**

e Cest une émergence qui n'a pas été marquée *e*P *e* 18 m 11 s *d* = [— 65]. Emergence parasite ? *avance provenant d'une anomalie* ? La formule des grandes distances s'appliquait exactement au séisme du 6 V. En tous cas, en adoptant l'épicentre publié, les PR_1 arriveraient à 21 m 40 s, résultat de calcul d'accord avec l'observation ; les PR_1 sont nets après 21 m 34 s.

2 VII 21h36m45s 3,5 S 128,5 E **Iles Moluques.**

e 18 m 36 s *d* = [6] Cette émergence correspond donc probablement aux P ; *e* S 29 m 26 s *d* = + 85. L'examen du séismogramme conduit à avancer les S de 32 secondes. Il subsiste donc un retard réduit à + 63s. Il est important de remarquer que *les stations de de Bilt et Uccle ont des retards du même ordre.* Il y a là un fait qui mériterait d'être expliqué.

6 VII 3h0m40s 15,7 S 167,3 E Nouvelles Hébrides.

*e*P 13 m 55s *d* = [+ 10] Les PR_1 sont nets après 23 m 20 s.
e (S) 34 m 20 s Emergence trop incertaine pour prêter à discussion.

11 VII 17h27m20s 40,0 N 14,0 E Mer Thyrénéenne.

e 2 m 40 s *d* = + 16 Ce n'est pas l'émergence des P. L'appareil vertical n'a pas fourni l'indication du début ; les horizontaux n'ont accusé qu'une faible déviation.

20 VII $0^h21^m35^s$ 50,0 S 127,0 W Pacifique.

e 19 m 45 s *d* = [— 12] Emergence douteuse

20 VII $3^h59^m30^s$ 34,0 N 14,0 E Méditerranée.

*e*P 3 m 33 *d* = — 10 L'émergence marquée *e* est bien *e* S 6 m 29 s *d* = — 10. Mais il n'est pas possible d'admettre une avance de 10 S.

26 VII $5^h12^m35^s$ 32°,7 S 73,7 W Côtes Chili.

Les phases sont peu distinctes. L'émergence des S est trop douteuse pour qu'on puisse discuter la différence *d* = [—] 112 indiquée pour les S.

30 VII $20^h6^m20^s$ 45°,0 S 16,0 E Nord Dalmatie.

P 1 m 53 s *d* = + 11 S 3 m 16 s *d* = + 14 Les P et les S sont nets ; il n'y a pas de correction possible à une seconde près. L'interprétation des S est bonne et la différence S-P conduit à la bonne distance. *Retards à expliquer.*

3 VIII $3^h2^m15^s$ 6,5 N 128,0 E Est Mindanao.

e 17 m 44 *d* = [— 18] C'est une émergence *e* et non *e*P ; le début est très faible, mais *il est remarquable qu'on trouve encore ici une avance.* L'interprétation très difficile des S explique la différence importante d = + 156.

3 VIII $19^h57^m10^s$ 27,6 S 66,3 W Nord Argentine.

L'appareil vertical n'a pas fonctionné ; il y a bien un *e*P après 14 m 40 et non 16 m 50 comme l'annuaire l'avait indiqué. Les PR_1 sont après 18 m 11 en bonne concordance avec le calcul. Pour S l'heure indiquée 24 m 51 s ne peut-être modifiée malgré la différence importante *d* = —71 s. L'émergence est nette. Il faut d'ailleurs remarquer que *la plupart des stations européennes indiquent des avances du même ordre,* notamment Uccle voisine de Strasbourg.

C'est un fait intéressant dont une explication s'imposerait. Les SR_1 sont nets à 32 m 27 s.

12 VIII $6^h20^m55^s$ 25,0 N 46,0 W Océan Atlantique.

Il n'y a rien à tirer de la discussion ; ce sont de simples émergences avec traces faibles.

13 VIII $2^h2^m45^s$ 18,5 S 63,5 W Bolivie.

*e*P 13 m 39 s *d* = + 11 *e* S 24 m 1 s *d* = — 35
*e*P étant très faible, la différence + 11 est possible. Mais l'avance de 35 s pour les S étonne, car à l'heure indiquée apparaissent de grandes périodes très nettes. *Anomalie.*

15 VIII $8^h16^m33^s$ 13,0 S 166,8 E Nord Nouvelles Hébrides.

P 19 m 8 s *d* = [— 32] Emergence nette sans erreur possible. *Avance déjà signalée pour les tremblements lointains.*

16 VIII $14^h41^m38^s$ 34,0 N 14,0 E Méditerranée sud Sicile.

*e*P 4 m 22 s *d* = + 39 Tremblement rapproché avec début sans doute trop faible.

20 VIII $16^h15^m28^s$ 38,0 S 73,5 W Pointe du Chili.

*e*P 18 m 32 s *d* = [+2] Les P sont bien indiqués. mais les S sont beaucoup trop tard *e*S 29 m 9 *d* = + 79. On ne saurait pourtant les mettre plus tôt. Groupe parfaitement net. Uccle indique le même retard. *Etude à faire.*

4 IX $14^h8^m55^s$ 51,0 S 3,0 E Océan Atlantique.

e 17 m 17 *d* = + 188 Ce n'est pas le début.

6 IX $14^h5^m24^s$ 43,5 N 11,2 E Italie Garfagnana.

*e*P 1 m 15 s *d* = — 7 2 m 6 s *d* = — 19. Il est impossible de placer les P et les S plus tard.

L'épicentre est connu sans ambiguïté (Lunignana Garfagnana, Apennin septentrional et Alpes Apuanes). *Il y aurait lieu de faire une étude détaillée de ces tremblements italiens au point de vue de la propagation*, en utilisant par exemple les tables de Mohorovicic et recherchant l'influence possible de la profondeur de foyer.

(Pour le tremblement suivant il n'y avait pas de vertical en fonctionnement; l'indication des horizontaux se trouve être exacte. Pour les suivants on constate des anomalies diverses, ce qui confirme l'opinion émise ci-dessus).

8 IX $1^h45^m35^s$ 22,0 S 180,0 Sud des îles Fidji.

*i*P 19 m 55 s *d* = [—5] pour S *e* (S) 32 m 13 incorrect. Confirmation du fait que les tremblements *de cette région ne donnent pas d'émergence nette pour les* S (au moins à Strasbourg et pour les Wicchert). Les P apparaissent au moment prévu si l'intensité du tremblement est suffisante.

9 IX $18^h56^m0^s$ 15,0 S 171,7 E Est Nouvelles Hébrides.

P 19 m 42 *d* = [— 5] pas de S nettes. Même observation que pour le précédent.

14 IX $2^h8^m45^s$ 41,0 N 21,5 E Grèce.

*e*P 3 m 49 s *d* = + 46 S 5 m 36 *d* = + 10. Forte agitation microséismique.

20 IX $14^h38^m50^s$ 20,6 S 168,8 E Entre Nouvelles Hébrides et Nouvelle Calédonie.

*i*P 19 m 53 s *d* = [O]. Mais ici encore il n'y a pas d'S nettes.

23 IX $19^h37^m0^s$ 49,0 N 156 0 E.

*e*P très faible sujet à erreur.

7 X $20^h54^m0^s$ 12°,0 S 69,0 W **Frontière Pérou et Bolivie.**

e (P) 13 m 30 s *d* = + 12 *i*S 25 m 40 s *d* = + 82
On peut avancer les P de 4 s. Pour les S il y a une emergence par ondes plates à grande période à 24 m 17 s d'où *d* = — 1.

13 X 23^h11^m55 34,7 N 19,3 E **Méditerranée.**

*e*P 3 m 50 s *d* = — 6 *e*S 6 m 20 s *d* = — 42.
Les P sont exacts; les S sont trop faibles pour la discussion.

16 X $11^h36^m30^s$ 50,4 N 31,6 W **Nord Atlantique.**

P 5 m 35 s *d* = — 6 S 9 m 59 s *d* = — 10.
Inscription faible, plutôt *e*S que S.

18 X $8^h11^m30^s$ 46,0 N 20,0 E **Albanie.**

*e*P 3 m 1 s *d* = — 1 *e*S 5 m 47 s *d* = + 23.
S est pris trop tard 5 m 29 s *d* = + 5.

22 X $10^h51^m47^s$ 7,0 S 145,0 E **Nouvelle Guinée.**

e 17 m 53 s *d* = + 107 émergence faible.

22 X $12^h9^m50^s$ 21,5 S 72,0 W **Pacifique, Côte Chili.**

*e*P 12 m 35 s *d* = — 93 *e*S 24 m 5 s *d* = — 106.
Malgré la grandeur de ces différences, il est impossible de corriger. *Anomalie.*

22 X $21^h35^m3^s$ 46,0 N 9,0 E **Nord Italie**

*e*P 1 m 10 s *d* = + 28 début très faible.

28 X $12^h50^m6^s$ 27,0 S 74,4 W **Côte du Chili.**

*e*P 14 m 11 s *d* = — 23 Début douteux.

15 XI $9^h20^m43^s$ 34,5 N 25,0 E **Région Crète.**

P 4 m 21 s *d* = — 8 S 7 m 40 s *d* = — 24.

Cette avance ne peut être supprimée d'après l'appareil vertical.

26 XI $8^h 51^m 0^s$ 40,0 N 20,0 E Albanie.

P 2 m 5 s $d = -57$; S 6 m 33 s. Erreur d'interprétation. Le début est à 2 m 59 $d = -3$. Pour les S il y eu confusion avec les L qui par interférence avec les S donnent des apparences trompeuses.

29 XI $8^h 2^m 45^s$ 59,0 N 149,0 W Nord Alaska.

*e*P 11 m 22 s $d = +1$ *e*S 9 m 33 s $d = -61$. S mal choisies *e*S à 20 m 31 s $d = -3$.

10 XII $4^h 25^m 35^s$ 39,0 S 74,5 W Sud Chili.

e 19 m 12 s *e* 28 m 25 s $d = +25$. Ce ne sont que des émergences sans netteté et non des *e*P et des *e*S.

11 XII $21^h 22^m 18^s$ 14,5 N 91,0 W Amérique centrale.

*e*P 12 m 49 s $d = +2$ Inscription très faible, pas de S.

16 XII $12^h 5^m 43^s$ 35,79 N 105,74 E Kan Sou.

Voir la Monographie publiée par Mlle Y. Dammann dans les publications du bureau central, Série B, et la discussion de ce séisme publiée par M. Turner dans l'International Summary.

Reçu en avril 1925.

ORGANISATION DES SERVICES SÉISMOLOGIQUES

The recording of seismologic data at the Dominion Observatory, Ottawa, Canada

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CONTENTS

Card forms (one card to an earthquake) are used. On these is entered all the information to be used in the work on the location of epicentres. All that is known in the office about any earthquake is to be entered in full or indexed on the card. The card forms are supplemented by other auxiliary record sheets.

The following account is a part of the information about to appear in Vol. VII, No. 3, of the Publications of the Dominion Observatory, under the title « The Organization of the Seismologic Division ».

The subject dealt with is here limited to the inter-relations of the seismic data files. In order that the routine as a whole may be understood, an account is first given of the entire section (The Seismic Records Group). This is supplemented by a schematic diagram indicating the same information graphically (Appendix A).

The press reading files (52.1; 52.2), the transition file (52.3) and the permanent card file (52.5) are alike so far as the rulings on the face of the forms are concerned. Most of the directions for the use of the files are alike and they are accordingly combined (General Instructions). Routine peculiar to each of the three groups follows, the supplementary files 52.8 and 53.9 being included in the outline for the permanent card file. A history of each, up to January 1, 1925, is added.

A sample of a filled-out press reading form is given in Appendix B ; a completed transition entry appears in Appendix C ; a set of 10 cards containing the records of earthquakes, Nos. 1910 to 1919, is the illustration furnished in Appendix D. (1).

It was felt that, for the purpose of this article, a de-

(1) Il n'a pas été possible de reproduire cette collection de documents adressés au Bureau Central et qui figurent dans sa bibliothèque, en particulier l'appendice D dont la coloration constitue le principal intérêt.

Note de la Rédaction.

tailed description of the other auxiliary files would be superfluous.

The Seismic Records Group

The most important interrelated group of files is that taking care of the records from the seismographs, the data deduced from them and the data received from other stations.

The daily weather maps recceived from the Meteorological Office, Toronto, together with the record sheets from the Calendar thermograph showing the continuous temperature curve at the Dominion Observatory, are grouped with the records from the Deformation Instrument and the seismograms registered on the Bosch, Wiechert and Milne-Shaw instruments.

A desk file (31.) is kept, in which each of these records is checked off as received. The dates, in consecutive order, are given each a single line on the form. Each instrument is given a vertical column. The weather maps have a column also. If the record or map for the day is received and is in good order it is checked off as it enters. If for any reason there is no record of any group or if the record is not normal, a note is made of the fact. In the case of the seismograms the serial numbers of the earthquakes on the sheets are noted.

File 31. is entered up by the seismologist in order that he may have brought before him as a matter of routine, a complete memorandum of the records as received and may always know how each instrument is functioning.

The seismograph sheets are changed each day about nine a.m. Record for parts of two days is therefore on each sheet. The date entered on the form is taken to indicate the records *begun* on that day. Thus in looking for information about a seismogram of an earthquake occurring, say at three a.m. (E S. T.) December 12, one would refer to the entries in the line for December 11. The weather maps are entered on the date line corresponding to the date on the map, not the date of receipt.

Owing to the pressure of other routine work, the Deformation records are not investigated further. They are stored in heavy, narrow, manilla envelopes in file 24.

The Calendar thermograph records are read for maximum and minimum temperature at Ottawa and the weather maps are examined to note the position of the « low » and the steepness of the barometric gradient near it. These facts are entered in file 06.1 after which the thermograph records are stored in 25.1 and the weather maps in 94.

The seismograms are examined for earthquakes which may be easily read, while they are still in the fixing bath. If such a record appears it is removed for reading as soon as possible. After the readings have been made it is returned to be washed along with the other records. As a rule only one of the seismograms of the earthquake is used for this preliminary reading. The time of arrival of P, the time O and the value of Δ, together with a short description of the record are telephoned to the press. The readings are entered in duplicate on paper forms. These are facsimilie copies of card forms used for the permanent files. One of the forms goes to the Director for his information. He files it in 52.1. The other is retained by the seismologist in file 52.2.

After the seismograms have been washed and dried and have been entered in file 31., they are examined for earthquakes. If such appear they are read by the assistant seismologist; the data being entered on paper forms similar to those used for the press readings.

All the seismograms are read for microseisms and the information entered in 06.1. The behaviour of the instruments (trouble with focussing, temperature control, time markings, etc.) as revealed by the records, is entered in file 06.2.

Those seismograms having no earthquakes recorded on them are now stored in heavy, wide, manilla envelopes in file 21.

The earthquake records read by the assistant seismologist are re-read by the seismologist. If these differ, both values are entered in the paper forms. A discussion of the readings results in an accepted set which is to be entered on the cards. The paper forms are preserved in file 52.3 and the cards in 52.5. The cards are «step-punched » and filed on Shannon arches.

The accepted readings are entered by the seismologist from the paper forms to the manuscript for the monthly bulletins. The manuscript is kept in file 15.5. At the end of the month the manuscript is compared by the assistant seismologist with the cards which he has filled out with the accepted readings from the paper forms. This serves to check all entries. The manuscript for the bulletins is now mimeographed. One set of the mimeographed bulletins is kept in the Director's office (15.91), one in the office of the seismologist (15.92) and one in the office of the assistant seismologist (15.93). The bulletins are mailed to about 230 stations. A copy of the bulletin is given to the stenographer who makes out the corresponding sheets of the same data in different form for the yearly report. These are kept on file 19.5 until the end of the year when the yearly report is made out for the printer and the data transferred to file 19.9.

The reports picked up from those broadcast by Strasbourg through the radio station Lafayette near Bordeaux are entered by the observer on duty, on special forms which are filed in 54. after the data have been entered on the card files 52.5.

The bulletins received from other stations are checked off, on receipt, in file 91. from which at the end of the month the monthly acknowledgment report is made out. The bulletins are kept in transition file 95.3 until the data can be entered on the cards. They are then kept in a steel cabinet where they will be readily accessible (95.5). After the earthquakes on the bulletins have become 18 months old the files are transferred, the bulk of the bulletins going to file 95.9, the reports from Oxford to 99.2 and those from Strasbourg to 99.6.

The entries on the backs of the cards in 52.5 include the values of O and Δ for each station reporting, as well as Ottawa such values can be deduced from the records at the various stations. The computations for *d* and *r* (the quantities required for stereographic projection work) are made and the circles drawn on the draughting sheets in 17.5. Each time the records for a month become 18 months old, the file for that month is closed. Photographs are made of the cards for the month, laid on a table with the indicator edges visible. Exposures are made for the face side and for the reverse. These photographs are bound into a book file (52.8) and at the end of the year a set of copies is made up to be sent to those observatories requiring them.

When the photographs have been made there is no longer any need of retaining the step-filing of the cards. They are accordingly transferred to cabinet drawers in file 52.9.

Each time a month's records are closed, the graph sheets in 17.5 are examined in conjunction with the corresponding cards and the location of the epicentre determined. These locations are then typed into the manuscript from which the publication « Location of Epicentres » is to be made up. The graph sheets are then put in file 17.9. The publication is to be sent to the printers as soon as the locations for a calendar year are complete, e. g. the « Location of Epicentres for 1924 » should be ready for printing in July, 1926.

The unbound publications received from other stations are to be entered as received in 91. They are thus acknowledged together with the bulletins, once a month. They are then to be bound in pamphlet folders, indexed and filed in 08.

General Instructions for filling in Press Reading, Transition and Permanent Card Files

52.1 ; 52.2 ; 52.3 ; 52.5

The instructions may be divided into five sections

A) Entries for the north-south component instruments (Bosch I and Milne-Shaw 23).

B) Entries for the east-west component instruments (Bosch II and Milne-Shaw 17).

C) Entries for the vertical component instrument (Wiechert 82 kgm).

D) Data obtained from the combined records of all the instruments.

E) Combined reports received from all the stations.

A. — NORTH-SOUTH COMPONENT INSTRUMENTS

(Bosch I and Milne-Shaw 23)

The readings made on the records produced by the north-south component seismographs (Bosch I and Milne-Shaw 23) are to be entered in the first group of spaces (comprising about a quarter of the card at the top). The form is so arranged that the phase letters up to and including eL, together with LR_1 if it occurs, are written in the margin spaces. This margin appears beyond the edge of the next card when the cards are « step-punched » and filed as directed (page 18). All the time-values are to be entered under the heading indicating the instrument from which they were obtained. The fact of the existence of the various phases up to and including *e*L determines the value of the record. This information, together with other data serving the same purpose, for a whole series of earthquakes (ten at a time on the

Shannon files, and a month at a time in the summary photographs) is made available at a glance by the method of punching and filing employed.

The phase letters after *e*L, with the exception of LR_1, are to be written in the column headed P in the second section of the group to the right of centre, as will be explained presently.

The first three lines in the left-hand half are for the entering of P, PR_1 and PR_2 *respectively* if these occur or for any e's or i's which appear, presumably at or after P and before S. The time-values are to be written in under h (hours), m (minutes), and s (seconds). The period (time in seconds to complete a full to-and-fro movement) is to be entered in the column under T. The readings from the Milne-Shaw seismograph are, in general, the only ones used to determine the true earth amplitude in microns. The columns headed F, a, a/2F and A_μ are to be used in computing and entering these facts. If check values are obtained from the corresponding Bosch record the reductions and results are to be written in the remarks division for the component concerned. The methods to be employed in reducing measured record amplitude to true earth amplitude for the Milne-Shaw and for the Bosch records will be explained presently.

The second three lines in the left-hand half are for the entering of S, SR_1 and SR_2 *respectively* if these occur or for any e's or i's which appear, presumably at or after S and before *e*L. The time-values are to be written in and the reductions for amplitude to be made as in the corresponding P wave readings in the preceding paragraph.

If any or all of the six phases above appear on the record each reading must be entered in the line reserved for it, but the e's and i's may be entered in any spaces left blank in the division to which they belong. If more e's or i's appear than can be accommodated in the division, the ones left over must be entered in the remarks for the component concerned.

The third group of spaces (two in number) is for the entry of *e*L and, if it occurs, of LR_1. In general the second of these lines appears blank, as LR_1 is seldom recorded.

The maxima and other noteworthy parts of the L wave phase are to be recorded in the second half of the section. The phase letters are to be written in the column headed P. The last line is reserved for the entry of the time when the tremors stop.

The reduction of the record amplitudes to true earth amplitudes for the Milne-Shaw seismographs is to be made as follows. Having read and entered the value of T for the point concerned, look up Plate N° 8. in the Milne-Shaw handbook. The value of F (the magnification factor) corresponding to the determined T can now be found on the right-hand edge if the magnification is theoretically 250, or on the left-hand edge if the magnification is theoretically 150. The magnification in use at the time can be ascertained by referring to the current bulletin sheets in file 15.5. Next read the record amplitude from turning point to turning point in millimeters and tenths. This gives a (the double amplitude) to be entered in the proper column. Under a/2F write a fraction whose numerator is 500 a and whose denominator is F. For example, if a = 3.6 mm. and F = 86 write $\frac{1800}{86}$ in the column headed a/2F. Performing the division yields the value of the true earth amplitude in microns to be written in the column $A\mu$.

Where a check amplitude reading from the Bosch records is desired the reduction is to be made as follows. The period T is that of the earth particle. In the magnification graph at the back of the Klotz Tables this value is denoted by T_e. Determine from the current bulletin sheets in file 15.5 the period of the undamped pendulum (denoted by T_0 in the magnification graph). Find the value of the ratio T_e/T_0. Determine the damping ratio in use by reference again to the current bulletin sheets.

Using the graph line corresponding to the damping ratio involved, find the ratio of actual to theoretical magnification for the determined T_e/T_o. Multiply this by the theoretical magnification (120) and set down F (the magnification factor). Determine a, a/2F, and A_μ exactly as in the reduction for the Milne-Shaw records. Set the values in order in the remarks space for the component read, indicating the phase to which they refer. The Bosch determinations have been found to agree with those from the Milne-Shaw to within about five per cent wherever the value for T_e has been certain. If they do not agree and no error can be found in the computations it will usually be found that the period is difficult to determine accurately.

The greatest of the maxima (A_μ) is to be put in the margin opposite « Maximum μ's ».

The direction of P, up or down on the sheet, is to be noted if possible. For the north-south components the interpretation of « up » or « down » on the sheet in terms of an earth shift to the north or to the south is to be made as follows.

Shift		Bosch I	M-S 23
Up	indicates an earth movement toward the	South	South
Down	» » » » » »	North	North

Indicate the direction of shift of P by S or N written in the margin in the space provided.

The velocity of the L waves as H (high), N (normal), or L (low) is to be noted in the margin by the proper initial.

The character of the L waves as Sin (sinusoïdal) or Ir (irregular) is to be written in the proper margin space. If the character is difficult to describe accurately either way, use Sin ? or Ir ?, depending upon whether the reader feels that it is more nearly sinusoïdal or more nearly irregular.

If e's or i's appear which seem to indicate perfectly definite phases which do not fit into the adopted scheme of readings, write x in the margin at Pecu. Phases (peculiar phases).

Any remarks applicable to only the Bosch I or Milne-Shaw 23 are to be written in the space for « Remarks N-S Record ».

B. — EAST-WEST COMPONENT INSTRUMENTS

(Bosch II and Milne-Shaw 17)

The entries for readings from the east-west component seismographs (Bosch II and Milne-Shaw 17) are to be made in the second group of spaces (comprising about the second quarter of the card). These are to be made exactly as in the case of those for the north-south components with the following exceptions.

The interpretation of up and down on the sheet in terms of an earth shift to the east or to the west is to be made as follows.

Shift		Bosch II	M-S 17
Up	indicates an earth movement toward the	West	East
Down	» » » » » »	East	West

Indicate the direction of shift of P by E or W in the margin space provided.

Any remarks applicable to the east-west component records only are to be entered in the space marked « Remarks E-W Record ».

C. — VERTICAL COMPONENT INSTRUMENT

(*Wiechert* 80 *kgm.*)

The readings made on the vertical component seismograph (Wiechert 80 kgm.) are to be entered in the third group of 13 spaces. The entries are to be made exactly the same as in the case of those for the north-south and the east-west components with the following exceptions.

In determining the value of the true earth movement there is no Milne-Shaw seismograph record and any reduction of record amplitude to true earth amplitude must be made from the Wiechert record. The reduction is to be made as directed for check readings from the Bosch except that the theoretical magnification should be found from the current bulletin sheet in file 15.5. In general the value is 160 but it may be set at less for various reasons.

The interpretation of up or down on the record in terms of the nature of the wave (condensation or rarefaction) is to be made as follows.

Shift		Wiechert
Up	indicates a wave of	Rarefaction
Down	» » » »	Condensation

The nature of the wave, if determined, is to be entered in the space provided to the right of centre in the vertical section.

The margin space opposite Cal. Azimuth (calculated azimuth) can be filled only when the nature of the wave is known from the vertical record and the shifts to the north or south and east or west have been readable. In that case the calculated azimuth may be obtained by reference to the following table.

N-S	E-W		Vertical R	Vertical C
Movement to North and	East	epicentre lies to	N-E	S-W
	West		N-W	S-E
Movement to South and	East	epicentre lies to	S-E	N-W
	West		S-W	N-E

The result is to be indicated by initials NE, NW, SE, or SW in the margin space allotted to the calculated azimuth.

Any remarks applicable to the vertical component record only are to be entered in the space following the title « Remarks V Record ».

D. — DATA OBTAINED FROM THE COMBINED RECORDS

Having read and recorded the seismograms, determine the most probable values for P and S. These are to be used in the computations for Δ and O. The computation scheme is printed on the form. This is always to be used in computing Δ and O from the times for P and S, as the work is then self-checking. Enter the values for S and P in their allotted spaces in the scheme. Subtract and put the value for S-P below. Turn to Table 5 (Klotz Tables) and find the value of Δ corresponding to the S-P obtained. Write this in opposite the Δ in the first line of the scheme. Look up in Table I (Klotz Tables) the value of I_P corresponding to Δ. Enter in the space provided. Subtract I_P from P and obtain O (the time at the origin). Write in the value and then subtract O from S obtaining I_s for entry immediately below. Look up the value of Δ corresponding to I_s as given in Table 6

(Klotz Tables). Put the figures after Δ in the last line of the computation scheme. The first and last entries for Δ must check if all the computations have been made correctly.

Turn the form about with the margin at the top and in the space opposite the first three lines of the computations write the value of Δ. In the space opposite the next five lines write the value of O. Keep the entry for O near enough to the dotted line that a second entry can be made above it and nearer the edge as will be explained below.

If the record is incomplete and no values for Δ or O can be obtained write the time of the first appearance of tremor in place of O, keeping it near enough to the dotted line that a second entry can be made above it and nearer the edge. Later, when locating the epicentre using the data from all the stations, the value of O may be obtained. If so it can then be written in the space left near the edge.

If it should be found that the O as computed from the Ottawa records does not fit in with the accepted O derived from all the records of other stations when the location of epicentres is being done, the accepted O is to be written above the O first entered Ottawa.

No confusion arises from these entries. If no value for Δ appears in the margin the time entered near the dotted line in the space opposite the last five lines of the computations scheme shows the time of arrival of the first tremors. If no other time is written in, O could not be found but the value entered serves to approximately fix on the time when the earthquake happened on the date given.

The records are to be evaluated on a scale of ten. Not the nature of the earthquake but the nature of the record obtained from it at Ottava is the basis of the estimate. Nos 1, 2, 3 and 4 indicate records which do not exhibit any preliminary phases which can be identified.

N° 1 is reserved for those traces which are just barely visible. N° 2 indicates fairly well-marked L waves but no earlier phases. Further, eL is not definite as to time of arrival. If eL is fairly defininite or if earlier traces appear, evaluate the record by N° 3. Where early traces appear and where eL is definite denote by N° 4. The early traces in this case cannot be read even tentatively as definite phases. There are different colored cards for different values of record. Records evaluated by N^os^ 1, 2, 3 and 4 are to be written on white cards only for file 525. The forms for the press readings and tentative readings (52.1 ; 52.2 ; 52.3) are on paper. These are all white — there is no color index.

N^os^ 5 and 6 indicate that P or S may be read quite definitely but not both. No value for Δ or for O can be determined from the records. The two numbers permit an indication of relative worth in this class. Records evaluated by N^os^ 5 or 6 are to be entered on buff only for file 52.5.

N^os^ 7 and 8 indicate that P and S are both recorded but that one or the other is doubtful. The derived values of Δ and O are thus doubtful and are to be surrounded by brackets. At this point it is to be noted there is a difference in meaning between the two entries,

*e*P (17-18-22) and *e*P ? 17-18-22

In the first case the reader feels reasonably sure that the phase recorded is really P but the time is uncertain either because of poor time marking or because the phase is so very faintly recorded. In the second case the time is quite certain but the reader is doubtful as to whether it should be read as P. It is possible that in some cases it would be necessary to write it,

*e*P ? (17-18-22).

The two numbers (7 and 8) permit an indication of relative worth in this class. Records evaluated by N^os^ 7 and 8 are to be tabulated on salmon cards only for file 52.5.

Nos 9 and 10 indicate complete records. That is, the deduced values for Δ and O are taken as being reasonably certain. The two numbers permit an indication of relative value in this class. No 10 is reserved for those records which are normal and very sharply marked. Records evaluated by Nos 9 and 10 are to be inscribed on blue cards only.

The duration of the record in hours and tenths of hours is to be entered in the margin space designated.

If the records from Halifax or Saskatoon are received they are to be read as completely as possible, the readings tabulated in the space devoted to general remarks and the fact of their being so received and read indicated by an *x* in the margin space opposite the name of each station reporting.

If the epicentre is known — from press reports or through other channels — indicate the fact by an *x* in the margin opposite « Known Epicen. » (known epicentre). Write the location and the source of the information in the general remarcks.

When the epicentre has been determined from the combined reports from all the stations denote the fact by an x indicating a determined epicentre. Write the latitude and longitude of the location in the general remarks.

After the records have become 18 months old and the evidence is all in and has been considered, the most probable position of the epicentre may be settled upon. The locations are usually in definite zones or belts. These zones have been numbered 1 to 10 according to the following plan.

I. — Japan and the Kurile Islands.
II. — China and Eastern Asia.
III. — East Indies and the Pacific.

IV. — South America.
V. — West Indies, Mexico and Central America.
VI. — Southwestern United States and Southern California.
VII. — Alaska and the Aleutian Islands.
VIII. — Western Asia.
IX. — Europe.
X. — Unclassified.

The number indicating the zone in which the earthquake happened is to be written in the margin space after Epic'l. Zone (epicentral zone). Until the work on the records is complete, probable epicentral zones may be indicated in pencil in the margin space provided.

After the location has been determined the verified azimuth is to be taken from the chart showing the traces on the map of the world of the various azimuth lines from Ottawa. This verified azimuth is to be entered in the margin opposite « Ver. Azimuth ».

The percentage of water path may be estimated from the globe as soon as the epicentre is known. The figures indicating this are to be written in the margin spaces provided.

Any remarks applicable to the records as a whole are to be written in the space headed « Remarks-General ».

Turn the form so that the margin is on top and away from you. Stamp the serial number in the space opposite the first four lines. In the case of the cards (52.5) stamp the serial number and the date on the reverse margin also, using the same relative positions for each. Press readings are all to be made, reported and recorded in Eastern Standard Time. The dates are to correspond to that time. All other readings and entries are to be in Greenwich Civil Mean Time. The dates are to correspond. When Daylight Saving Time is adopted for Ottawa it is to be ignored so far as time on the records is concerned. It is not to be used in fixing the time on the seismograms themselves nor in the press reports issued or recorded.

Ordinarily the record is first read by the assistant seismologist and the entries arranged on the paper form (52.3). He is then to initial the form in the space after « Read ». The records are re-read by the seismologist who initials the form in the space after « Reread ». No other check marks will be needed in this case.

The seismologist writes the earthquake report in the bulletin manuscript, using the paper form as the source of his information. The assistant seismologist enters the accepted readings on the cards, from the same source. When a manuscript sheet is filled the assistant seismologist checks it with the *card entries* thus checking all the entries at once.

If an earthquake is read or re-read by both readers working together, both initial in the space after the proper designation.

If for any reason the records are being read and verified by the same person, the readings on the form are to be carefully checked after entry with the seismograms themselves. In this case initial after Rec-Sl (record to slip). Then on filling out the bulletin manuscript from the form 52.3 an initial or check mark is to follow Sl-MSS (slip to manuscript). Never initial in the check spaces until the verification it vouches for has been carefully done.

The date when the earthquake was read must always be recorded in the space after « Date Read ». The date on the press reading may differ from that on the transition form. The entry on the latter is to be copied onto the card along with the record data.

The press reading forms and the cards (25.1 ; 52.2 ; 52.5) may be considered as final records in each case. For these an initial in the space provided at the bottom indicates the person responsible for the transcription. The initials in the check spaces on the transition form are to be copied onto the cards. These indicate the person or persons responsible for the readings.

The paper forms (52.1 ; 52.2 ; 52.3) are filed on Shannon arches, the holes being punched always in the same position on the sheet. The gauge is set for centre punching foolscap sheets and the records so punched lie in a pile one immediately above the other.

The card forms are « step-punched ». The gauge is provided with ten divisions (0, 1, 2, 3, 4, 5, 6, 7, 8, 9). It is set for the last figure of the serial number of the earthquake recorded on the card and the perforations made. Care must be taken to insert the card always with the face side (on which are entered the Ottawa records as already described) *down*. The cards are to be kept on Shannon arches as described in the instructions for file 52.5 (page 29). The punch marks on succeeding cards being « staggered », the cards when on the arch reveal the data on the margin edge for all the earthquakes in each group of ten.

E. — COMBINED REPORTS RECEIVED FROM ALL THE STATIONS

As soon as the data for Ottawa have been entered on the face of the cards the Ottawa entry on the reverse is to be filled in. (There is no reverse ruling on the paper forms 52.1 ; 52.2 and 52.3). Enter P, S, L, O, and Δ if they have been determined. If not, enter the time of the first trace in the space below P, S, or L depending on the reader's estimate of the probable phase first recorded. Indicate whether the first trace is sharply defined or not by the use of *i* or *e*.

Where Δ is known, look up the quantities *d* and *r* corresponding, in the Ottawa list of Table 14 (Klotz Tables). The checking of the *d* and *r* determinations is to be done before the circles are drawn. The check form appears thus, the rulings extending to the bottom of a full sheet.

d	*r*	Stations	Serial No	Δ	*d*	*r*

The form is kept on the desk until the entries for the day have been made, after which all determinations may be checked and the projection circles drawn.

In the case of this station enter « Ottawa » in the column headed « *Stations* », write the serial number of the earthquake and the computed value of Δ in the space provided and look up *d* and *r* in Table 14, interpolating where necessary. Enter the values in the right-hand *d* and *r* columns. The circles for location work are to be drawn after the *d* and *r* values have been re-computed. It will be better to wait until the bulletins from other stations, received that day, have been digested into the card forms and the *d* and *r* values are all ready to be checked at once.

The entry of data from the bulletins from other stations on the cards is to be carried out as follows. Let us suppose the bulletin for December has been received from Pulkova. Take the cards for the period reported on (December) and examine them one at a time, beginning with the first one in the month.

If no record was obtained for the earthquake, according to the report, enter a short dash in the margin opposite the printed station name (Pulkova). The time of the earthquake appears in the Ottawa entry at the top of the card. Care must be taken to avoid recording some earthquake registered at Pulkova but not at Ottawa among the data for the earthquake registered at Ottawa but not at Pulkova. Check the time of day carefully.

The simple line in the margin indicates that the report from Pulkova has been received, covering the time of the earthquake entered on the card, and that no trace of it was registered there. (Compare instructions, p. 102).

If the record was obtained at Pulkova but no values were obtained for Δ and O enter the outstanding phases in the Pulkova spaces. Entries of *e* and *i* may be made in the spaces devoted to P, S, or L provided the nature of the phase is indicated by a letter. If no letter appears, the time alone in the space implies that the phase recorded is that designated by the letter at the top of the column. Write a small circle (o) in the margin space opposite the station name. This indicates that some traces were registered at Pulkova but that no complete data were obtained.

If an earthquake appears in the Pulkova bulletin for which no corresponding record appears in the Ottawa cards it is to be passed over.

If the record obtained at Pulkova for an earthquake on the Ottawa cards is complete, compute Δ and O from the P and S given using the computation scheme explained above (page 101). Do the work in pencil on the Pulkova bulletin itself. The work is thus preserved if questioned at any time. This insures too that location of epicentre work is all based on the same tables. Enter the material exactly as in the case of the Ottawa records in which Δ and O are obtained. Write *x* in the margin opposite the name of the station. This indicates that the record was obtained and that it was complete.

If the station does not appear on the card, write the name on one of the blank lines at the bottom and complete the entries as already explained except that no margin entry is to be made. Further, if the record is incomplete, it need not be written up at all. If a station appears frequently in the blank spaces, the cards for the next year are to have the name of that station printed in its proper alphabetical order in the list.

When the records and bulletins for the day have been digested into the records, the values for *d* and *r* are to be recomputed. Fold under the two columns on the checking list containing the d's and r's already obtained, and repeat the work, setting out the results in the left-hand columns. When all are finished spread the sheet and compare the values. Make any corrections required and then draw the circles as instructed in file 17.5. Where possible the checking should be done by another computer. In any case the values are to be carefully verified before the circles are drawn. A check mark in the narrow column provided on the card, entered in line with the station, indicates that the circles have been drawn for that earthquake and station.

The cards are to be kept on the Shannon arches in file 52.5 until the earthquakes recorded on them are 18 months past. The final work for the location of epicentres is then to be done as explained in the detailed instructions for files 52.5 and 17.5.

Press reading files

52.1; 52.2

DETAILED INSTRUCTIONS

1. Examine the smoked sheet record of the Wiechert vertical first thing in the morning. If an earthquake record appears change the photographic seismograph sheets at once and have the development of the sheets rushed. While waiting for them, change the vertical and make preliminary readings of the record.

2. Even though no trace appears on the vertical the photographic sheets are to be examined as soon as they are fixed. If a record is seen which may be read for distance, select the most legible sheet. After a preliminary washing it may be removed long enough to permit a press reading to be made.

3. Read the record for P, S, and L and any other phases which may be especially well marked. Compute Δ and O, using the computation scheme as explained in the general instructions (page 101). Compute Δ in miles by multiplying the distance in kilometers by .621. Verify the answer by dividing the sum of the digits in the answer by nine. There must be no remainder. The distance in miles should not be expressed beyond the nearest ten miles.

4. The readings are to be given in Eastern Standard Time. The date is that of O (the time at the origin). Carefully verify all the readings and the date.

5. Compare two of the paper forms by holding one above the other in front of a strong light, making sure that the form has the same registration with respect to the edges on both. Insert a carbon sheet and run the three into the typewriter. Adjust left and right so that two digits just fit into the column headed *h* on the left, and on typing along with the space bar, three digits just fit into the column headed A_μ on the right. Adjust up and down to the line. Test the registration before typing in the readings.

6. Type the readings on the forms as directed in the general instructions. Use that part of the sheet belonging to the record used for the press reading. Type the multiplication for reducing kilometers to miles in the remarks space to the right of the Δ and O computation. The typing of the readings, computation for Δ and O, and the multiplication by .621 can be done directly on the form. Once the sheets are set in the machine the registration with the typewriter is fixed over the whole form and a little experience makes recording and even computing and multiplying quite as rapid on the machine as by hand. In the remarks, type a report to be telephoned to the press. Use the same general outline every time. A sample is given below. The italics indicate the stereotyped part. The normal type shows a typical entry.

Any information given the press must be based on well-established readings only (see section 12 below). The example given is the press report for october 16, 1924.

Δ	3070	
S	11-34-14	
P	11-29-26	3070
S-P	4 48	621
I_p	6-03	3070
O	11-23-23	6140
I_s	10-51	18420
Δ	3070	1906470

An earthquake **of moderate intensity** *was registered at the Dominion Observatory* **last night, October** 16. *The first preliminary tremors arrived at* 11-29-26 **p.m.,** *Eastern Standard Time and the distance to the epicentre was* 3070 *kilometers, or* 1910 *miles. The time at the origin was* 11-23-23. *The record continued for* **an hour.**

(Telephoned to the Citizen and Journal at 10-30 a.m., Oct. 17).

Type in the time the report was telephoned to the press and indicate to which papers it was given. In general, all press reports are to be sent to both papers. If special card reports are sent out, indicate the fact, stating to whom they were mailed. Fill in such margin spaces as may be readily done from a wet sheet. If very marked maxima occur they should be read and recorded. Evaluate the record as directed in the general instructions (page 102) and insert the estimate number in the margin. If more than one person was engaged in reading the record, type a single initial in each of the spaces after « Read ».

8. Return the sheet to the wash water as soon as possible.

9. Examine file 52.2 to find the serial number of the last press report sheet (upper right-hand corner). Type the next number on the form before removing it from the typewriter.

10. Remove the form, turn it and insert again so that the margin space comes uppermost. Look up the serial number of the earthquake (31). Type the values for Δ and O and the date and serial number in their proper places as directed in the general instructions (pages 101 and 105).

11. Write in the date when the record was read and initial the sheet in the space at the bottom of the form.

12. Telephone the report to the papers, being careful to give no details other than those typed on the form. Require a « repeat » from the reporter in every case. Do not answer leading questions. Do not indulge in guesses as to the location, etc. (see section 6 above).

13. Set the punch for centre on foolscap sheets and perforate original and carbon copy at the same time.

14. File the original on the top of file 52.2.

15. Deliver the copy at once to the office of the Director, to be filed on the top of file 52.1.

16. When passing the vertical seismograph during the day and when leaving at night turn on the light and examine the record for large earthquakes. If any appear develop one photographic record, change the sheet, and make a press report at once. If called upon at any time by the press or others, examine the records carefully, developing a record if it seems worth while (all local earthquakes can be found on the vertical). If a record appears, a press reading is to be made. The entries are to be made and the report issued as directed above, regardless of the time of day or night when the work is done. The carbon copy is to be taken at once to the Director's room.

HISTORY TO JANUARY 1, 1925

The file was begun in December 1923. The first press reading to be handled as instructed above was for the earthquake N° 1672, December 22, 1923. The paper slip was not the full-size sheet but a form similar to the rulings for one component on the present sheets. These smaller sheets were used from report N° 1 up to and including report N° 21, August 14, 1924.

The full-size sheets begin with report N° 22 for earthquake N° 1885, september 13, 1924. They continue to report N° 35, december 28, 1924.

The press reports previous to the opening of this file were handled much the same but no copies were kept and there was a lack of uniformity in the routine and in the matter of forwarding memoranda for the information of the Director. The only records now on hand for press reports previous to December 22, 1923 are in the press clippings in the scrapbook (070) and in the correspondence file (02.9) under the division devoted to memoranda to the Director.

Transition file

52.3

DETAILED INSTRUCTIONS

1. As soon as the seismograph sheets have been developed, washed and dried they are examined by the seismologist. The necessary entries are made in desk file 31. and in the instrument performance file 06.2. Those sheets showing traces of earthquake records are put in heavy manilla envelopes, the sheets for a single day by themselves. With them is included a paper form for the transition reading. On it are entered the serial number of the earthquake and the Greenwich Mean Time date. The serial number may be determined from the entries in file 31. If more than one earthquake record is on the sheet extra forms are included, one for each earthquake, each, with the date and serial number written on. If any of the seismograms for the day have no trace of the record they are treated as « non-quake » records and left out of the envelope.

2. The envelope with the « quake » sheets, together with the separate « non-quake » records, is passed to the assistant seismologist who makes the readings of the earthquakes, entering them on the paper forms. The readings are made as complete as possible and are arrang-

ed on the form as directed in the general instructions. All the sheets are read for microseisms and instrument behaviour (06.1 and 06.2) and the non-quake sheets are now filed in 21.

3. The assistant seismologist returns the sheets and reading forms to the envelope, together with a blue marking card to be used for identification purposes later, and passes it to the seismologist for re-reading. When that is done and the entries on the form are checked and marked with a check symbol, the seismologist enters the data on the manuscript sheet for the monthly bulletin (15.5).

4. The blue marker card is clipped to the envelope, indicating that the data have been checked. The whole now returns to the assistant seismologist who enters the data on the card of proper color as outlined in the general instructions. The « quake » sheets are stored in file 22.

5. The paper form is now centre punched and put on the top of the ones already in place on the Shannon arch (52.3).

6. As the arch becomes unwieldy, the forms are to be transferred to box files to be given the same number.

HISTORY TO JANUARY 1, 1925

The file was begun in september, 1924. The first form of this type filed was that for earthquake 1872, September 4, 1924. Since that time the filing has been regular as outlined above.

The last transition reading form for 1924 is that of earthquake 1948, december 30.

Previous to September, 1924, the reading slips, as they were called, had been kept roughly in envelopes. The ones preserved extend back as far as 1915. Many were lost and, no doubt, in many cases none were made. But, in an irregular fashion, most of the slips have been preserved. These have been gathered together, sorted into chronological order and filed in the boxes to which the number 52.3 has been given.

Permanent card files

52.5; 52.9; 52.8

DETAILED INSTRUCTIONS

1. The card on file 52.5 must be the location or the index of every bit of information noted with respect to the earthquake recorded thereon.

2. The entries into this file are to be kept constantly up to date, both as regards the original issuing of the cards and the entering up of subsequent data received from other stations, read in current literature or deduced from the work done on the location sheets. (See the general directions for recording).

3. After the transition readings have been checked by the seismologist, the assistant seismologist enters the records on the permanent cards in this file.

4. Eighteen Shannon arches are maintained, one for each of the seventeen months just completed and one for the current month. The cards are kept sorted on their proper archs. At the end of each month the one containing the oldest records is removed and the cards taken off. All the earthquakes entered on them have now become at least 18 months old. The vacated arch is to be used for the current month just beginning. The cards are ready now for their final entries.

5. Use the material on the cards together with that in file 17.5 to locate the epicentre of each earthquake for the month. All data that have appeared to date are to be found in these two files. Having determined the epicentre fill in the latitude and longitude in the wide space at the top of the card (reverse), left blank for the

perforations. Fill in any margin spaces for which the location work has furnished the required information.

6. The photographs of the margins are now to be made as follows. Pin the cards on a draughting board, all face up, with the margins showing for the whole month as they showed for each group of ten earthquakes when they were on the arch. Photograph them, full size. Repeat the process with the reverse sides up. These photographs are to be bound into book form, a month to a page. The file number is 52.8.

7. Transfer the cards to the cabinet drawers (52.9). They are to be filed, in order, face out, earlier numbers to the front of the drawer. The step filing is now abandoned. The photographs of the margin edges have taken its place.

HISTORY TO JANUARY 1, 1925

The file was begun December 1, 1923. Until August 1, 1924, six small cards (4″ × 6″) were used for recording the data now in a single large card (6.5″ × 12.2″). The rulings were pratically the same and the routine of entering data, similar.

The small card series runs from earthquake 1661, December 2, 1923 to earthquake 1842, July 29, 1924. The first card of the large size records earthquake 1843, August 1, 1924 and the last card in 1924 is for earthquake 1948, December 30.

Previous to December 1923, the routine of checking between seismologist and assistant seismologist was much the same as that outlined above and in the general directions. The work lacked the uniformity and continuity of the present system where the routine is regulated by definite written instructions. The earthquake readings, microseism observations, behaviour of instruments, etc., were all entered chronologically in record books. The entries from November 1, 1907 to March 31, 1919 were made in Vol. I to Vol. V inclusive. There was no separation of material up to this time. From April 1, 1919 to november 30, 1923 the station data were kept in two separate sets of books. The earthquake readings and correlation of microseisms with meteorologigical data were recorded in Vol. VI-A and Vol. VII-A for this period. The record runs consecutively through the two volumes. The log of the station is to be found in Vol. VI-B and Vol. VII-B. These two log books run concurrently for the period. The former is that kept by the assistant seismologist, the latter that by the seismologist. In Vol. VI-B a tally system was begun in which appears a record of the bulletins received from other stations. This serves as the first material for file 91. and the reverse entries of 52.5 In Vol. VII-B is included a diary of the seismologist, the initial material for file 32.2.

The record books (nine altogether) are kept in file 51. In all these except volumes VI-B and VII-B there is no arrangement of material except a chronological one. The B volumes are divided into sections as is a ledger, the various subjects being arranged according to an index, the entries in the sections being made chronologically.

It is to be noted that so far as the readings of the seismograms and the microseisms are concerned, the records are quite complete and uniform from November 1, 1907 to November 30, 1923. The card records introduced after the latter date arranged the readings into a form to lessen the routine work, insure the recording of more details from all seismograms according to a programme and render the information more accessible.

Previous to December, 1923, the reverse side entries (P, S, L, Δ, and O) were made on printed forms. The *d* and *r* computations were made, for some years, on pad paper and thrown away. Later they also were tabulated and filed. The forms for this required a second entry of Δ and O. A complete set of the printed forms for comparative data, from January, 1908 to November, 1923, is on file 52.9. A set of the computations for *d* and *r* is preserved on the same file for the period January, 1916 to November, 1923.

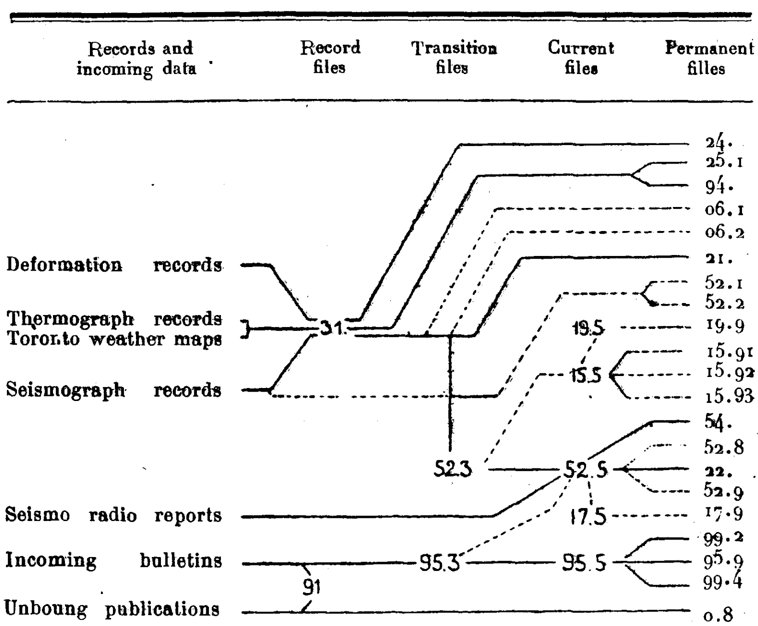
Dominion Observatory, Ottawa, Canada.
Jan. 27'25.

Reçu en février 1925.

APPENDIX A

THE RECORDING OF SEISMOLOGIC DATA AT THE DOMINION OBSERVATORY, OTTAWA, CANADA

Diagram of the seismic record files



Whole lines indicate movements of original records and bulletins.
Broken lines indicate movements of extracts from original data.
Dotted lines indicate movements of extracts from secondary data.

APPENDIX B

1917

	Bosch NS				Milne-Shaw No 23										P	Bosch NS				Milne-Shaw No 23								
	h	m	s	T	h	m	s	T	F	a	a/2F	Au				h	m	s	T	h	m	s	T	F	a	a/2F	Au	

Direction P.	Remarks N-S Record
VL-H.N or L.	
V-Sin. or Ir.	
Maximum u's.	
Pecu. Phases	

	Bosch EW				Milne Shaw No. 17								P	Bosch EW				Milne Shaw No 17							
	h	m	s	T	h	m	s	T	F	a	a/2F	Au		h	m	s	T	h	m	s	T	F	a	a/2F	Au
eP					3	03	41																		
ePR1					3	06	30																		
S					3	12	26																		
eSR1					3	17	02																		
eSR2					3	20	00																		
eL2					3	24	.5																		

?	Direction P.	Remarks E-W Record
N	VL-H.N. or L.	
Ir.	V-Sin. or Ir.	
	Maximum u's.	
	Pecu. Phases	

Vertical				Vertical							Remarks V Record
h	m	s	T	h	m	s	T	F	a	a/2F	Au
											Initial Impulse
											Condensation Rarefaction

	Cal. Azimuth		Remarks--General
	VL-H.N. or N.		An earthouake of moderate intensity was registered
	V-Sin or Ir.		at the Dominion Observatory, Monday, Oct. 20, The
	Maximum u's.		first preliminary tremors arrived at 3-03-41 p.m.,
	Pecu. Phases		E.S.T. and the distance to the epicentre was 7320
2-52-56 7320	Δ	7320	Kilometers or 4550 miles. The
	S	3-12-26	time at the origin was 2-52-56.
	P	3-03-41	7320 The record continued for an hour
	S-P	8-45	621 and a half.
	Ip	10-45	7320
	O	2-52-56	14640
	Is	19-30	43920
	Δ	7320	4545720
8	Val. Rec. 1-10		
1.5	Duration Hrs		(Telephoned to the Citizen and Journal
	Halifax Rec.		at 10-45 a.m. Tuesday Oct. 21, 1924)
	Saskatoon "		
	Known Epicen		
	Deter'm'd "		
	Epic'l Zone		
	Ver. Azimuth		
	Water Path		
October 20'24	Read- H D		
	Reread		
	Rec-51		
	51-MSS		
	Date Read		
	Oct. 21'24		
	Initialled		

Chronique de la section de séismologie de l'Union géodésique et géophysique internationale

depuis la deuxième assemblée générale à Madrid en octobre 1924.

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1. Comités nationaux ou commissions séismologiques nouvellement constitués

TCHECOSLOVAQUIE

Comité national de Géodésie et de Géophysique. — Liste des Membres.

L. Benes, Commandant, Chef de la Section de Géodésie et d'Astronomie à l'Institut géographique militaire de Prague.
S. Hanzlik, Professeur à l'Université de Charles de Prague.
B. Kladivo, Professeur à l'Ecole polytechnique tchèque à Brno.
V. Laska, Professeur à l'Université de Charles de Prague, Membre de l'Académie, Président du Comité.
F. Nusl, Directeur de l'Observatoire national de Prague, Membre de l'Académie.
J. Pantoflicek, Professeur à l'Ecole polytechnique tchèque à Prague, Membre de l'Académie, Secrétaire du Comité.
J. Petrik, Professeur à l'Ecole polytechnique tchèque à Prague.
A. Semerad, Professeur à l'Ecole polytechnique tchèque à Brno.
R. Schneider, Directeur de l'Observatoire national de Météorologie. à Prague.
J. Smetana, Directeur de l'Institut hydrologique d'Etat à Prague.
B. Salamoun, Professeur à l'Université de Charles de Prague.
J. Vancl, Ingénieur Hydrologue à Prague.

Bureau

V. Laska, Président.
J. Pantoflicek, Secrétaire.

Section de Séismologie

V. Laska, B. Salamoun.

2. Correspondance

Le Secrétaire de la Section a adressé aux divers délégués la lettre ci-dessous :

Circulaire n° 1

Strasbourg, le 28 janvier 1925

Monsieur le Délégué et cher Collègue,

La conférence de Madrid a décidé que chaque nation aurait droit à deux exemplaires au minimum des publications de la Section de Séismologie de l'Union Géodésique et Géophysique Internationale par unité de cotisation. Mais elle a indiqué que les nations pourraient demander un nombre supplémentaire d'exemplaires en cas de nécessité, ce nombre maximum étant également fixé à deux par unité de cotisation.

Vous auriez droit ainsi, votre cotisation étant de... unités à ... exemplaires minimum,... exemplaires maximum.

Les procès-verbaux de la conférence de Madrid étant actuellement à l'impression, je vous serais reconnaissant de me faire savoir d'urgence le nombre d'exemplaires que vous jugez utile à votre pays.

Veuillez agréer...

En réponse à cette circulaire les chiffres suivants sont parvenus au Secrétariat :

Unités de cotisation	Pays	Délégués	Nombre d'exemplaires demandé
1	**Afrique du Sud.**	(**Secretary for Mines et Industry**-Pretoria).	1
2	Australie.	(M. Pigot).	
2	Belgique.	(M. **Somville**).	4
8	**Brésil**	(M **Morize**).	16
2	Canada.	M. Hodgson).	6
1	Chili.	(Legacion de Chile. — **London**).	
1	**Danemark**	(M. Nörlund).	4
3	**Egypte.**	(**M. Wade**).	6
8	**Espagne.**	(M. Galbis).	32
8	**Etats-Unis d'Amérique.**	(M. Reid).	32
8	France.	(M Rothé).	32
8	Grande-Bretagne.	(M **Turner**).	
1	**Grèce.**	(M. Eginitis).	3
8	**Italie.**	(M. Oddone).	24
8	**Japon.**	(**M. Tanakadate**).	32
1	Maroc.	(M. **Liouville**).	
3	**Mexique.**	(M. **Sanchez**).	
1	Pérou.		
8	Pologne.		
2	**Portugal.**	(M **de Carvalho**).	6
2	Siam.	(M. **Salvidhan**).	4
2	Suède.	(M. **Akerblom**).	8
1	Suisse.	(M. de Quervain).	4
5	**Tchécoslovaquie.**	(**M. Nusl**).	
1	**Urugay.**	(**M. Sicco**).	

Une deuxième circulaire a été adressée à MM. les Délégués des Nations et MM. les Directeurs d'Observatoires.

Circulaire n° 2

Strasbourg, le 25 avril 1925

Monsieur et cher collègue,

Vous recevrez à bref délai les comptes rendus des séances de la section de Séismologie de la 2me conférence tenue à Madrid. Bien que quelques communications soient parvenues très tard, le manuscrit a pu être remis à l'imprimerie au commencement de janvier. Une épidémie, manque de personnel et de caractères, ont empêché l'imprimeur de tenir les promesses qu'il avait formellement prises. Le tirage s'effectue actuellement et la distribution sera imminente.

Le secrétaire, qui désirait une publication immédiate, s'excuse de ce retard absolument indépendant de sa volonté.

Il appelle l'attention des membres de la section sur trois points :

1° Il prie Messieurs les délégués qui ne l'auraient pas encore fait, de bien vouloir lui indiquer le plus rapidement possible le nombre d'exemplaires dont leur section a besoin et le mode d'envoi qu'ils préfèrent. (pp. 47-48-57.)

2° Il signale la liste des publications de l'ancienne association en stock à Strasbourg dont des exemplaires pourront être envoyés contre remboursement. (Annexe V.)

3° Il demande à Messieurs les Directeurs d'Observatoires de bien vouloir examiner le vœu relatif aux échanges de personnel et de bien vouloir lui indiquer les échanges qu'ils proposent, afin que des démarches puissent être faites auprès des gouvernements intéressés. (pp. 93-93).

Veuillez agréer...

Plusieurs fascicules des travaux scientifiques (série A) et des monographies (série B) sont actuellement en préparation. Messieurs les membres des comités de l'Union qui désireraient y publier des travaux sont priés de bien vouloir les adresser d'urgence au Bureau Central, 38 Bd d'Anvers, à Strasbourg (Bas-Rhin).

Le secrétaire prie également toutes les personnes qui pourraient fournir des renseignements intéressant la vie de la section de bien vouloir les lui faire parvenir.

E. Rothé.

TABLE DES MATIÈRES

ACHEVÉ D'IMPRIMER
PAR LES
PRESSES UNIVERSITAIRES
DE FRANCE
49, B[d] S[t]-MICHEL, PARIS
EN AOUT 1925.