# Observations of Lg and Rg waves and remarks about the nature of $Lg_1$

SAVARENSKY E. TH. and VALDNER N. G. (*)

Ricevuto il 7 dicembre 1960

The result of the seismic sounding in the Black Sea (1) showed that to the South of the Crimean peninsula the granitic layer is interrupted in the deep part of the sea.

The preliminary data about the weakening of the Lg and Rg waves when they propagate through the central part of the Black Sea was exposed in our previous work (**) and by M. Bath (2).

The further investigation consists in finding the clear waves Lg on the continental paths. We succeeded in this comparing the records of waves at stations Tiksi from the earthquakes of two groups. The first group of earthquakes: Mongolia, Pamir, Southern China. The second group: Aleutian Islands, Kamchatka, Kuril Islands, Japan.

For the Mongolian earthquakes very sharp beginnings of waves, especially $Lg_1$, having great amplitudes with the period of 2 to 4 sec are observed. On the records of the station Tiksi clear waves Lg and Rg are noticed (fig. 1). For the earthquakes of Southern China these waves are clear, however the amplitudes are smaller and the periods of the waves are greater than previous. On the whole the first group of the paths corresponds to the continental structure of the earth's crust. The mean values of the velocities of these waves are: $Lg_1$ — 3.53 km/sec; $Lg_2$ – 3.31 km/sec; Rg – 3.05 km/sec.

For the epicentres of the Aleutian Islands no clear beginnings of the waves Lg and Rg are distinguished. The period of 18 to 24 sec with the superposition of rather weak waves of short period is predominant on the records of surface waves (fig. 2). The direction of the paths in

---

(*) Paper read at the Helsinky Assembly of the I.U.G.G., 1960.

(**) « Annali di geofisica », XIII, n. 2, 1960.

this case passes through the deep part of the Bering Sea (H ≈ 3.5 km) where the granitic layer seems to be interrupted or absent. For this region seismograms of 12 earthquakes are interpreted.

The group of the epicentres of Kamchatka, the Kuril Islands and Japan does not present a clear pattern of the interruption of the granitic

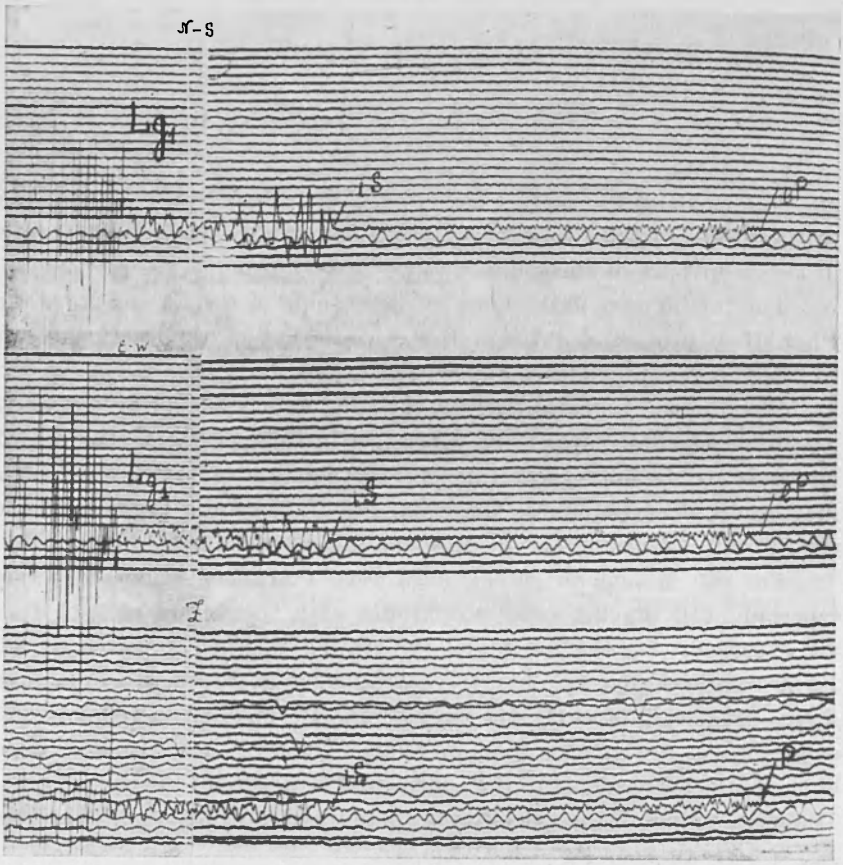


Fig. 1. – Copy of a seismogram of the seismic station Tiksi with clear $Lg_1$ wave.

layer or the continental structure of the earth's crust. In this case seismograms with the Lg and Rg waves and without them are available. This can be explained by the presence of a deep part in the Okhotsk Sea (H = 3 km) on the path of the propagation as well as the Kuril trench which has some effect creating the breakings of the granitic

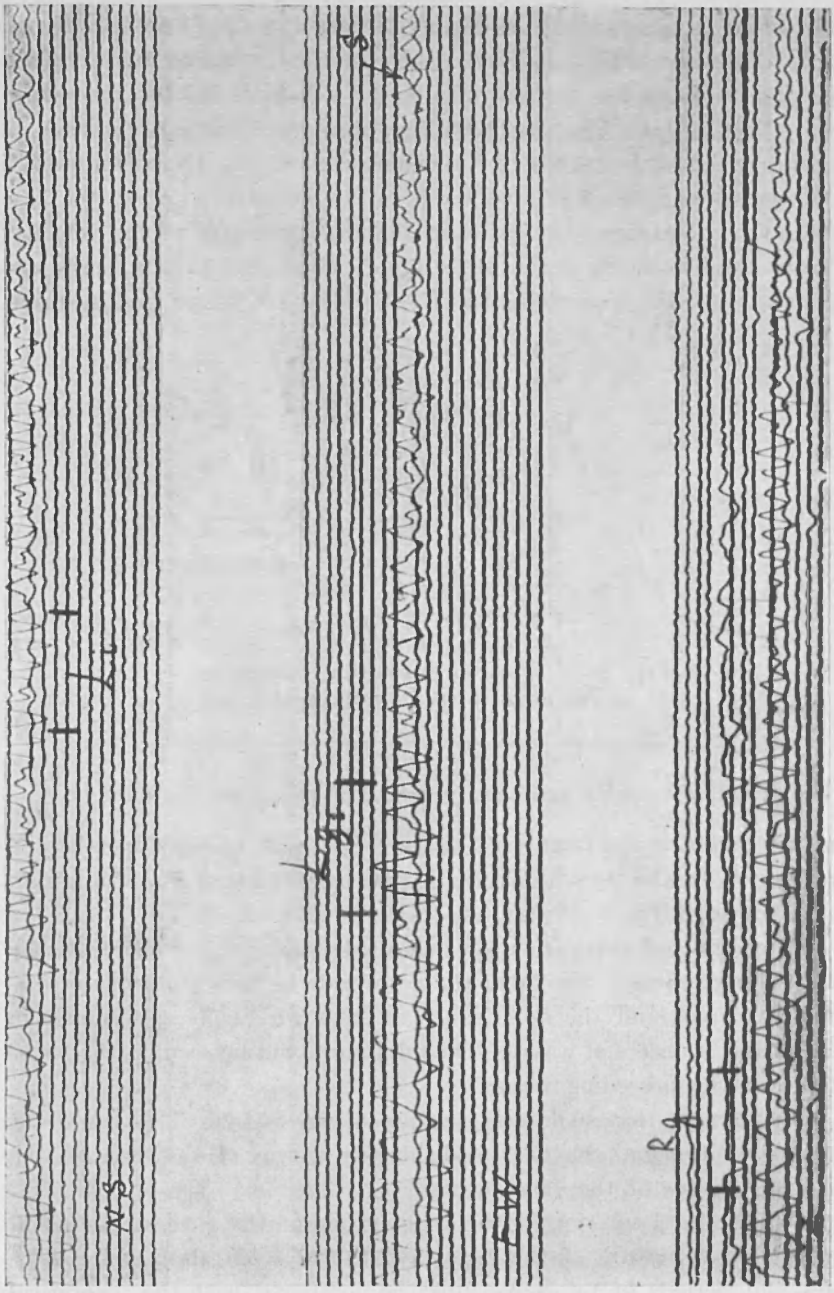


Fig. 2. – Copy of a seismogram of the seismic station Tiksi where Lg and Rg waves are absent.

layer. This is the cause of the doubtful cases and the disappearance of Lg and Rg on records. 26 earthquakes of this group are investgated. For some of them the mean values of the velocities are the following: $Lg_1$ — 3.50 km/sec; $Lg_2$ – 3.29 km/sec; Rg – 3.06 km/sec.

Fig. 3 shows the results of the calculations of the dispersion curves of the group velocities for Love waves in the two layered crust ([3]). The ordinate axis represents the ratios of the group velocity to the velocity of transversal waves $b_1$ in the upper layer. The abscissa axis represents the value reversly proportional to $kH$; ($H = h_1 + h_2$) expressed in terms

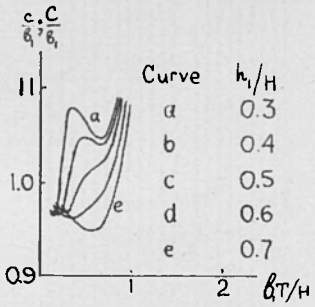


Fig. 3. – Plot of dispersion curves of Love waves in the two-layered crust.

of the period $T$ velocity and the thickness of the crust $H$, namely $\frac{b_1 T}{H}$. The parameter of the family of curves is the ratio of the upper layer's thickness $h_1$ to the total thickness of the earth's crust $H$. The group of the curves in fig. 3 corresponds to the first mode.

The family of curves for the first mode shows the presence of the points of maximum. For them the amplitude in the conditions of dispersion is great and the appearance of such waves on a seismogram will form as if onsets of waves. The maximum will be seen on the background of the preceding waves.

We suppose that such is the nature of waves $Lg_1$. This wave corresponds to the maxima on the dispersion curves of the first as well as higher modes of the Love wave.

For the final solution of the problem about the correctness of our explanation of nature of the $Lg_1$ wave the observed data of the velocities and periods of $Lg_1$ wave must be compared with the theoretical curves in fig. 4. The comparison of empirical results with the curves was made on different assumptions about the thickness of the earth's crust.

Families of curves are plotted in fig. 4. The abscissa axis represents the period in sec., the ordinate axis — the value of the velocities based on the assumption that $b_1 = 3.3$ km/sec. Each straight line corresponds to the points of the maximum for the dispersion curves of the first mode of the Love wave at different values of the total thickness of the earth's

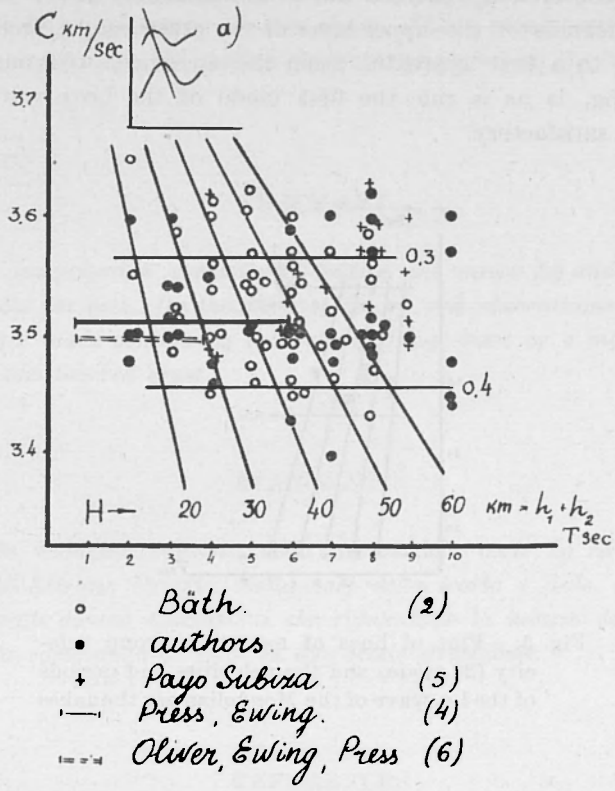


Fig. 4. – Plot of lines of maxima (group velocity 1st mode) and the velocity and period of the $Lg_1$ wave by different authors.

crust from 20 to 60 km. The horizontal straight lines on this chart correspond to different values of the ratios of the thickness of the upper granitic layer $h_1$ to the total thickness of the crust $H$. Points designate the values of velocities and the periods of their onsets obtained from observations by different authors: for the propagation of waves from the Black Sea earthquakes to Swedish stations by Bath (2), for the waves from the Black Sea earthquakes to the Moscow and Simferopol stations by the authors, for the waves propagating through the USA

continent by Press (4). The data of the $Lg_1$ wave from various earthquakes obtained at the Toledo seismic station by Payo Subiza (5) and finaly the data obtained by Oliver, Ewing and Press for the Arctic (6). On the whole the points corresponding to the observation data on the chart for the thickness of the crust from 20 to 60 km. However their scattering considerably exceeds the 60 km thickness of the crust. The relative thickness of the upper layer of the crust ranges from 0.25 to 0.45. Thus to a first approxim- ation the agreement with our assumption that $Lg_1$ is as a rule the first mode of the Love wave can be considered satisfactory.

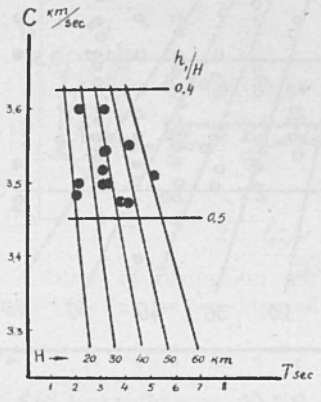


Fig. 5. – Plot of lines of ma- xima group velocity (2d mode) and the velocities and periods of the $Lg_1$ wave of the Mongolian ear thquakes

More detailed comparisons show that the $Lg_1$ wave can correspond also to the second mode of the Love wave. This is suggested by the fact that on the path of the propagation of waves from Mongolia to the station Tiksi the thickness of the earth's crust is sufficiently great. If to use the formula permitting to estimate the crustal thickness on the basis of relief (7) (or the map given in the same paper) the crustal thickness on this path must be of the order of 45 km approximately, the same thickness would be obtained by means of the method of A. A. Treskov (8). If to extrapolate the data obtained in the process of the deep seismic sounding of the Northern Tien Shan (9) to the path from Mongolia to North then the crustal thickness must also be estimated equal to 40-45

km and the relative thickness of the granitic layer can be considered equal to 0.3-0.5. Fig. 5 is a chart of the straight lines for the points of the maximum on the group velocity curves of the second mode of the Love wave with different crustal thickness. The points representing the velocities and the periods of the $Lg_1$ at the station Tiksi from Mongolian and Chinese earthquakes when the beginnings of $Lg_1$ were the most clear are also plotted on this chart. These points agree with the presented data about the crustal thickness expected on the investigated path.


## *SUMMARY*

*This investigation consists in finding the waves Lg and Rg on the paths in the far east. On the bases of theory and observations some conclusions are made concerning the nature of $Lg_1$ wave as a mode of Love waves in two layered crust.*

## *RIASSUNTO*

*Questa indagine consiste nella ricerca delle onde Lg ed Rg lungo i tragitti nell'Estremo Oriente. Sulla base della teoria e delle osservazioni vengono tratte alcune conclusioni che riguardano la natura dell'onda $Lg_1$ considerata come onda di Love in due croste stratificate.*


## REFERENCES


(1) NEPROTCHNOV YU. P., *Deep Crustal Structure under the Black Sea to South-West of the Crimea from Seismic Data.* « Dokladi Acad. Nauk. », **125**, 5, 1119, (1959).

(2) BÅTH M., *The Elastic Waves Lg and Rg along Eurasiatic Paths.* « Arkiv for geofisic » (Stockholm), **2**, 13, 295, (1954).

(3) DORMANN J., *Numerical Solution for Love Wave Dispersion on a half Space with Double Surface Layer.* « Geophysics », **24**, 1, 12, (1959).

(4) PRESS F., EWING M., *Two Slow Surface Waves across North America.* « Bull. Seism. Soc. Am. », **43**, 3, 219, (1952).

(5) PAYO SUBIZA, *Report During V European Seismological Comission, Spain,* 1959.

(6) Oliver I., Ewing M., Press F., *Crustal Structure of the Arctic Regions from the Lg Phase.* « Bull. geol. Soc. Am. », **66**, 9, (1955).

(7) Demenitzkaya R. M., *Techniques of the Study of the Structure of the Earth's Mantle Crystal Part.* « Soviet Geology », 92, (1959).

(8) Treskov A. A., *Results of the Determination of the Crustal Thickness from Observations of Distant Earthquakes.* « Bulletin of the Seismological Council of the USSR », Acad. Sci. USSR, **6**, 76, (1957).

(9) Kosminskaya I. P., *Crustal Structure from Seismic Data, Bulletin of the Moscow Society of the Nature Investigators.* « Section of Geology », **33**, 4, 25, (1958).