DEEP REFLECTIONS AND CRUSTAL STRUCTURE IN THE HUNGARIAN BASIN

J. GÁLFI and L. STEGENA
State Geophysical Survey and Geophysical Institute,
Eötvös University, Budapest
(Received: 15th August, 1959)

SUMMARY

According to earlier and recent reflection measurements the thickness of the crust in Hungary is 24 kilometres on the average, with a gabbro layer of 4 to 5 kilometres mean thickness. The thickness of the crust increases at the basin centre, with smaller values all around. The results of reflection and refraction work agree well and the results of earthquake evaluations also fit into the picture.

The deep-reflection work of the previous years (1,2) was resumed in the IGY. This paper contains the new results and the joint evaluation of all measurements hitherto performed.

The new measurements were carried out in *Putnok* [6], in the neighbourhood of *Szerencs* [7] and Szolnok [8]. The Tótkomlós deep reflection was obtained in the course of routine seismic work. The localities of the earlier [1—5] and recent [6—7] deep reflection measurements are plotted on an isostatic anomaly map of Hungary (Fig. 1). The map is based on a recent recomputation of the gravity network (3) and therefore it differs somewhat from the isostatic anomaly map shown in our previous papers.

A recording which is characteristic of our new set of measurements is that of *Szolnok* [8]. Between 1,8 and 2,0 sec there is the reflection of the basement, and after an empty strip there is an uncertain reflection around 6,0 sec. At 8,28 sec there is a well-defined arrival, with subsequent reflection traces. A less well-defined deep reflection with, however, a good line-up occurs at 9,56 sec. The deep-reflection recordings of *Hajduszoboszló* [1] were of a similar structure. After the reflection from the basement there is likewise an empty strip, with two deep reflections at 7,45 and 8,62 sec limiting a zone of arrivals. Therefore, the 8,28 sec reflection of Szolnok was correlated with the 7,45 of Hajduszoboszló and the 9,56 of Szolnok with the 8,62 of Hajduszoboszló. The early arrivals were considered to be reflections from the Conrad interface, the latter ones from the Mohorovičić interface. This assumption was corroborated by a deep refraction profile between Szolnok and Hajduszoboszló (4). Let us state that there is no repetition of reflections in our seismograms, so that the arrivals which are considered to be deep reflections cannot possibly be multiple reflections. That part of the Szolnok recording which shows the deep reflections is presented as Fig. 2.

In the record of *Putnok* no reflection occurs from the basement. At 6,0 sec there is a well-defined arrival. At 7,45 sec and 8,55 sec there are reflections with good line-up, with traces of reflections in between. The Szerencs seismogram is similar: an unclear arrival around 6 sec, good reflections at 7,25 and

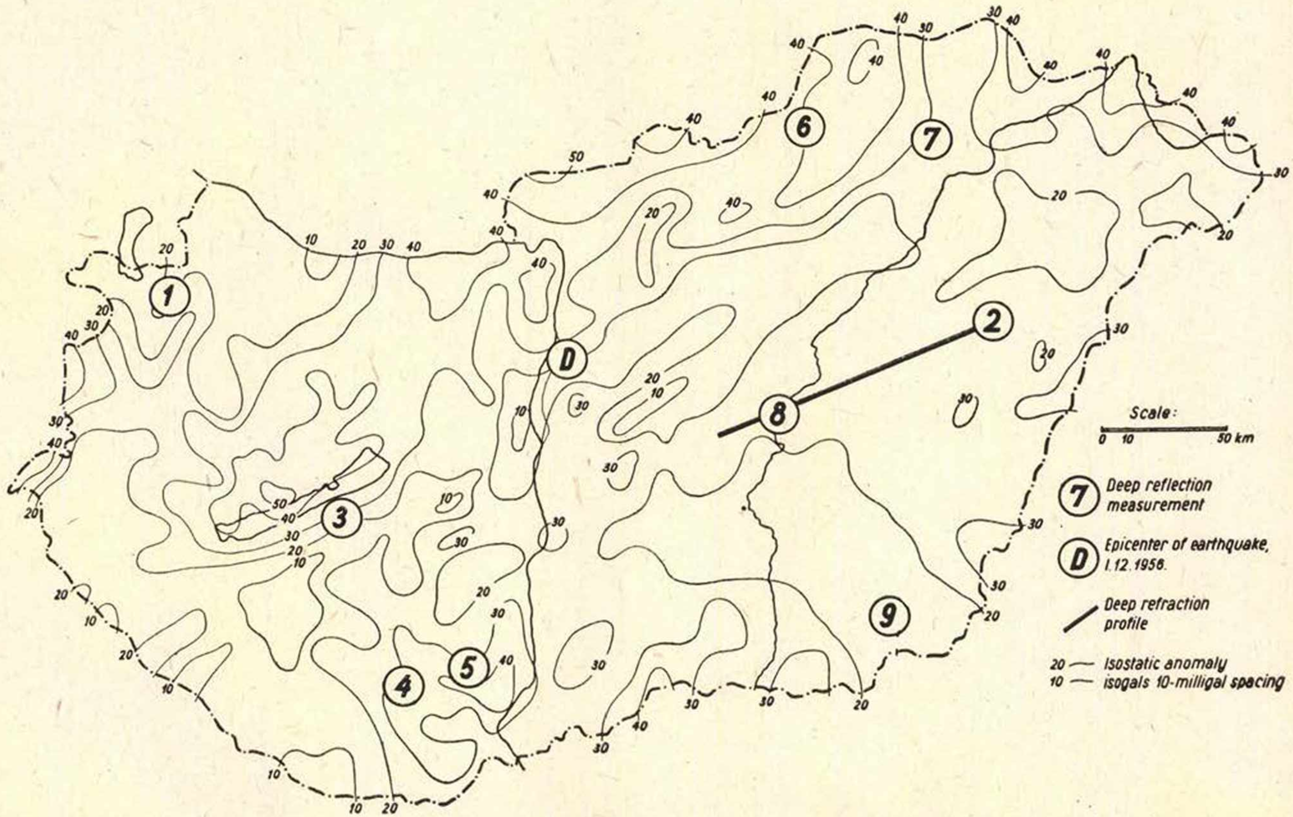

Fig. 1. Distribution of deep reflection and refraction measurements in Hungary in comparison with the isostatic anomalies

8,25 sec. The traces of reflections between the two well-defined arrivals are also present. This is illustrated by part of a seismogram from Putnok, showing deep reflections (Fig. 3).

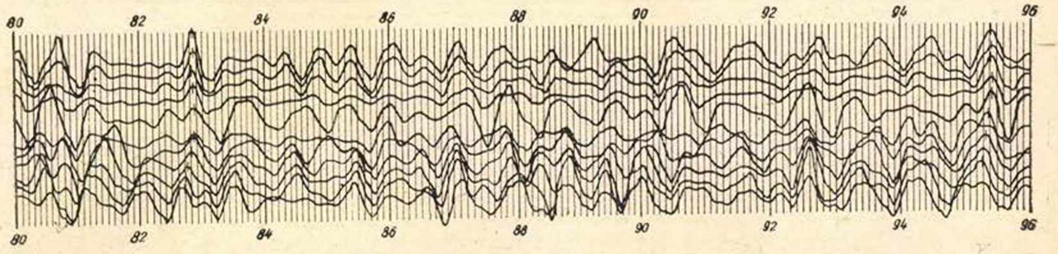

Fig. **2.** Part of the deep reflection recording at shot point 8 (Szolnok)

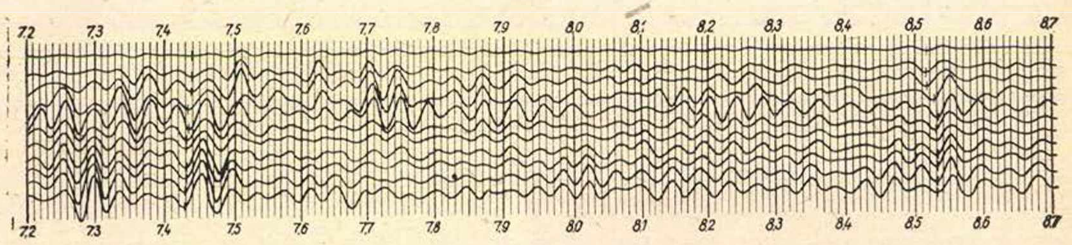

Fig. **3.** Part of the deep reflection recording at shot point 6 (Putnok)

In the *Tótkomlós* seismograms, two characteristic reflections of good line-up, also conspicuous by an amplitude increase, occur at 7,30 and 8,30 sec respectively, limiting a strip of very weak reflection traces.

Of the deep-reflections above mentioned, we will refrain for the time heing from an interpretation of the arrival at 6,00 sec. Of the rest, the early ones are considered to correspond to the C o n r a d interface, the latter ones to the M o h o r o v i č i ć interface.

All the seismograms were taken with apparatus of Hungarian make. The geophones employed were low-frequency ones (7 cps). In the Szolnok case low-pass filtering was employed with an upper frequency limit of 60 cps, in the rest of the cases a narrow-band resonance filtering of 30 to 40 cps peak frequency. The waves were generated with 150 to 400 kilograms of dynamite per shot, distributed into 5 to 7 holes of 20 metres depth and fired simultaneously. The Tótkomlós reflections were obtained by a charge of some kilograms of dynamite in a single hole.

To determine the depth of the seismic interfaces we have thought the relatively loose sediments (clayey-sandy Tertiary and somewhat better consolidated thin Mesozoic) to be removed, i. e. we have, to simplify computations, corrected the travel times to the surface of the crystalline basement. The data necessary for correction are listed in Table 1.

It must be pointed out that the depth of the crystalline basement in the cases of Szerencs and Putnok was indicated neither by seismic work, nor by deep drillings, so that the depth and average velocity values necessary to

Table 1.

Serial	Locality	Thickness km	Wave velocity km/sec	Correction time sec
of measurement		of sedimentary overburden		
6.	Putnok	1,8	2,4	1,50
7.	Szerencs	1,8	2,4	1,50
8.	Szolnok	2,5	2,4	2,08
9.	Tótkomlós	1,5	2,4	1,25

compute the correction were extrapolated from neighbouring territories, by taking into consideration the B o u g u e r anomalies of gravity.

The vertical average velocity, for the crystalline basement and the rocks situated below was, as contrary to our earlier investigations, computed this time from Hungarian data, namely from the deep-refraction profile (4). Accordingly, the average vertical velocity of the zone consisting of crystalline basement and granite layer was considered to be 5,7 kilometres per sec, down to the C o n r a d interface. The boundary velocity of 6,65 kilometres per sec, obtained for the gabbro layer, can be used as layer velocity down to the M o h o r o v i č i ć interface. In our previous publications the crustal thickness was computed by applying seismic velocities from Germany. It was now recomputed with the Hungarian velocity values. The travel times and the depths of interfaces are listed in Table II.

Table 2.

Serial	Locality	Travel-time		Depth below surface	
of measurement		Conrad	Mohorovičić	Conrad	Mohorovičić
		interface (sec)		interface (km)	
1.	Sopron	6,82	7,83	16,3	19,7
2.	Debrecen	7,45	8,62	19,2	23,2
3.	Karád	7,78	—	20,8	25,2*
4.	Pécs	7,57	9,25	21,5	27,2
5.	Bonyhád	7,52	9,62	19,1	25,9
6.	Putnok	7,45	8,55	18,8	22,6
7.	Szerencs	7,25	8,76	18,2	23,2
8.	Szolnok	8,28	9,54	20,2	24,5
9.	Tótkomlós**	7,30	8,30	18,8	22,3
	Average			19,2	23,6

* = extrapolated value.

** = values kindly communicated by the Seismic Department of the Hungarian Oil Trust.

The travel-time data are uncorrected and, accordingly, the depths of the interfaces are measured from the topographic surface. The *Karád* [3] recording has lacked the Mohorovičić reflection. Therefore the value of total crustal thickness was computed by adding to the depth of the Conrad interface the average thickness of the gabbro layer (4,4 kilometres), as computed from the rest of the seismograms. To facilitate the visualizing of the results we have drawn crustal profiles for each of the shot points (Fig. 4). The column "Mean value" is composed of the average thicknesses of the individual layers. For the sake of comparison we have added an average column of the refraction line, under the heading "Refraction", as well as the crustal profile computed from the *Dunaharaszti* earthquake, 1956 (5), which is an average for a very large area.

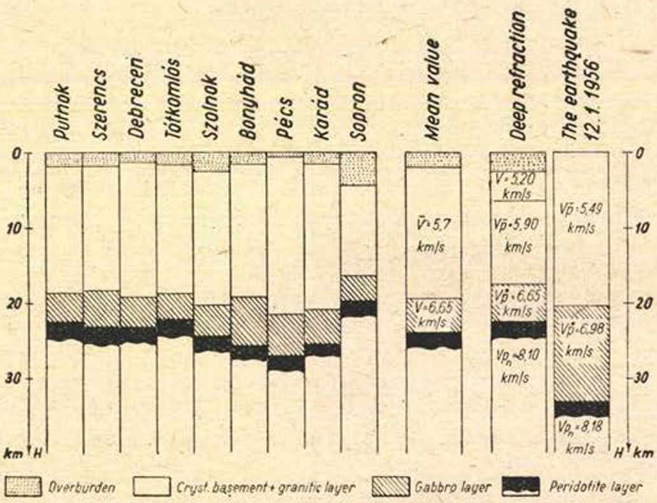

Fig. 4. The structure of the crust in Hungary

The "continental" nature of the Hungarian part of the crust, i. e. the existence of a thick granitic layer below the crystalline basement, is proved in good quantitative agreement by the entire bulk of data. If we consider in the following the crystalline basement to be part of the granitic layer, we may state that the continental granite layer in Hungary is — with some deviations — 19 to 20 kilometres thick. As to the intermediary layer of gabbroid constitution, the results of reflection and refraction measurement agree quite well on a thickness of 4 to 5 kilometres. The value of 12 to 13 kilometres, computed from earthquake data, lies somewhat farther off. We have already pointed out elsewhere (4) that this is probably due to the fact that the Dunaharaszti earthquake was registered at a number of observatoires where crustal structure significantly differs from that of the Hungarian Basin. Therefore, in spite of this apparent contradiction, the presence of a gabbro layer of small thickness beneath Hungary is considered to be proved.

A question open to criticism in our days is that of the existence of an intermediary layer of gabbroid composition, i. e. the problem of the subdivision of the crust (6). Measurements in Europe and especially in Germany point to the existence of a well-defined and contiguous basaltic or gabbroid layer (7); even the threefold subdivision of the crust was proposed in some instances. In the Hungarian refraction profile an "intermediary layer" with a velocity of 6,65 kilometres per sec for the compression wave was readily detected. The pairs of well-defined reflections in the recordings also point to the existence of a gabbro layer. The definiteness of the reflections — indicative of the sharpness of the transition in elasticity — is by no means uniform. In the Hajduszoboszló seismogram the Mohorovičić reflection is well-defined, while the Conrad is rather poor. In Szolnok the Mohorovičić reflection is indicated only by line-up, while the Conrad reflection is conspicuous by its elevated amplitude and pulse-like wave shape. At Tótkomlós both reflections are well-defined, at Putnok and Szerencs both are poor.

It is further remarkable that at almost all of the stations there occur intermediary reflections of variable intensity. Considering all that, it is more appropriate to speak in Hungary of a more or less well-defined, layered zone of transition between crust and mantle.

A well-defined reflection at 6,0 sec, occuring in a single record (Putnok), may indicate the presence of a further interface (Förtsch discontinuity?). The interpretation of this reflection necessitates further research.

The distribution of crustal thickness in Hungary is seen in Fig. 4. The crust is thinner beneath stations **(6. 7. 2. 9)**, situated in the east of the country, than in the central parts **(8. 5. 4. 3)**. The Sopron reflection also indicates a thinner crust **(1)**. The thickening of the crust in the direction Hajduszoboszló to Szolnok is corroborated by the refraction profile. The dip of the Mohorovičić interface is, according to that profile, about 1,50° due west. The average dip obtained by reflection is somewhat less, about 50°.

It is expedient to compare reflection results in Hungary with those abroad. (A comparison with refraction and seismological results is — because of the differences in methodology — not attempted for the present.)

The German measurements were carried out North of the Alps (Swabian Platform 7, 8, 9, 10, 11, 12), in the Rhine valley around Strasburg and Mainz (9, 13) and on the southern border of the northern German Plain.

The picture is completed by French measurements West of the Alps (14, 15, 16). The measurements around the Alps are liable for comparison inasmuch as, just as the ones of Hungary, these were situated in the neighbourhood of a young mountain chain. The data for comparison are listed in Table 3.

Table 3.

	German Plain	Strasburg	Mainz	Swabian platform	Hungary
Conrad interface ..	12—14	17—18	13—20	17—20	19
Mohorovičić interface	—	—	—	28—30	24

There is almost no difference as regards the depth of the Conrad interface. However, the gabbro layer is significantly thicker. It thins out somewhat on the western rim of the Alps (16), although not so much as in the Carpathian Basin. The total crustal thickness is by 6 to 8 kilometres greater than in Hungary.

In general, the data seem to indicate that the Hungarian part of the crust is relatively thin. The gabbro layer, of rather uniform thickness, is also thin. Towards the centre of the basin the thickness increases, due to the increasing thickness of the granite layer, with almost parallel dips of C o n r a d and M o h o r o v i č i ć interfaces.

REFERENCES CITED

1. G á l f i J.—S t e g e n a L.: Szeizmikus reflexiós méréssel meghatározott néhány adat a földkéreg magyarországi részéről. (Some results of the reflection seismic method concerning the structure of the Hungarian part of the Earth's crust.) *Geofizikai Közlemények,* **6,** 1—2. 1957.

2. G á l f i J.—S t e g e n a L.: Tiefenreflexionsversuche in Ungarn. *Geol. Rundschau,* **46,** 26. 1957.

3. R e n n e r J.: A magyar gravitációs alaphálózat végleges feldolgozása. (Final elaboration of the measurements of the national Hungarian network of gravity bases.) *Geofizikai Közlemények,* **VIII.** 105—141. 1959.

4. G á l f i J.—P á l o s M.: Kísérleti refrakciós kéregkutatás a Magyar medencében. (Experimental refraction investigation of the crust of the Hungarian Basin.) *Geofizikai Közlemények,* 1959. (In press.)

5. B i s z t r i c s á n y E.—C s o m o r D.: Az 1956. január 12-i földrengés és a Föld kérgének felépítése a Magyar Medencében. (The earthquake of Jan. 12., 1956 and the structure of the Earth's crust in the Hungarian Basin.) *Geofizikai Közlemények,* **6,** 37. 1957.

6. B e d e r k e, E.: Zur Geologie und Geophysik der Tiefen. *Geol. Rundschau,* **45,** 231—233. 1957.

7. S c h u l z, G.: Reflexionen aus dem kristallinen Untergrund im Gebiet des Pfälzer Berglandes. *Zeitschr. f. Geophys.* **23,** 225. 1957.

8. C a l o i, P.: The crust of the Earth from the Appennines to the Atlantic. *Zeitschr. f. Geophysik,* **24,** 65. 1958.

9. C l o s s, H.: Explosions en Allemagne, 1956—1958. Lecture delivered in the Utrecht (1958) session of the European Seismological Council (CSE). Abstract in *Bergakademie,* **10,** 7, 401, 1958.

10. R e i n h a r d, H. G.: Steinbruchsprengungen zur Erforschung des tieferen Untergrundes. *Freiberger Forschungshefte,* **C 15,** 28—44. 1954.

11. R e i c h, H.: In Süddeutschland seismisch ermittelte tiefe Grenzflächen und ihre geologische Bedeutung. *Geol. Rundschau,* **46,** 1. 1957.

12. R e i c h, H.: Über seismische Beobachtungen bei den grossen Steinbruchsprengungen in Blaubeuren. *Geol. Jahrbuch,* **68,** 225. 1953.

13. D o h r, G.: Ein Beitrag der Reflexionsseismik zur Erforschung des tieferen Untergrundes. *Geol. Rundschau,* **46,** 17. 1957.

14. B e a u f i l s, Y. etc.: Enregistrement des ondes séismiques provoquées par des grosses explosions. *Travaux Scientifiques, Série A. Publications du Bureau Central Séismologique International,* **19,** 327—329. 1956.

15. R o t h é, J. P.: Les expériences seismiques dans les Alpes en 1956. *Comptes Rendus de C. N. F. de Géod. et Géophys,* **79,** 1956.

16. L a b r o u s t e, Y.: Explosions dans les Alpes françaises. Lecture, delivered in the Utrecht (1958) session of the European Seismological Council (CSE). Abstract in *Bergakademie,* **10,** 7., 401. 1958.