1996

Seismogeological Features of the Crust in Romania

V Mocanu

C Dinu
University of Bucharest

F Radulescu

M Diaconescu

Camelia C. Diaconescu
University of South Carolina - Columbia, camelia@geol.sc.edu

See next page for additional authors

Publication Info

Published in *EAGE Special Publication Series*, ed. G. Wessely & W. Liebl, Volume 5, 1996, pages 289-299.
Monacu, V. I., Dinu, C., Radulescu, F., Diaconescu, M., Diaconescu, C., & Pompilian, A. (1996). Seismogeological Features of the Crust in Romania. *EAGE Special Pubication, 5,* 289-299.

Seismogeological features of the crust in Romania

V. I. Mocanu[1], C. Dinu[1], F. Radulescu[2], M. Diaconescu[2], C. Diaconescu[2] and A. Pompilian[2]
[1]*Bucharest University, Faculty of Geology and Geophysics; 6 Traian Vuia St., PO 37, Bucharest, Romania.*
[2]*National Institute for Earth Physics, PO Box MG-2, Bucharest-Magurele, Romania.*

ABSTRACT: The Romanian area consists of old consolidated units of pre-Alpine age (the Moesian, Moldavian and Scythian platforms) and Alpine orogenic units (the Carpathian arc and North-Dobrudjan orogen). General seismogeological peculiarities of the pre-Alpine tectonic units are presented, as well as some structural characteristics of the Transylvanian Basin and the Pannonian Depression. Both shallow and deep seismic reflection/refraction data as well as log information and some potential field data were used for the investigation of the crustal structure. The variability in the seismogeological pattern and crustal thickness shown by the different tectonic units is due to the differences in structure and lithology as well as to differences in crustal age. Some general characteristics are presented as an overall seismogeological image.

KEYWORDS: *seismogeology, foreland, platforms, crustal features*

INTRODUCTION

Romania belongs to the young Alpine European area, except for the northeastern region which is part of the old East European Platform of Epi-Proterozoic age, and the southeastern zone, representing the northern half of the Moesian Platform, of Epi-Palaeozoic age (Dumitrescu & Sandulescu 1970; Cornea & Lazarescu 1980). This paper represents a synthesis of seismic information (reflection, refraction and log data) from the Carpathian foreland regions (Moesian and Moldavian platforms), and the internal Transylvanian and Pannonian depressions.

The Moesian Platform is characterized by seismic markers fom the base of the Sarmatian, the surface of the Upper Jurassic–Lower Cretaceous limestones, the Triassic dolomites, and the top of the Palaeozoic calcareous complex (Diaconescu *et al.* in press).

The Moldavian Platform shows a particular feature represented by the Badenian anhydrite layer. The Mesozoic sequence, consisting of correlatable reflections disturbed by many diffractions generated by the pre-Neogene erosion level, is the second clear observable sequence. The Palaeozoic formations are characterized by sporadic low frequency reflections, unconformably covered by the younger deposits. The sedimentary/basement boundary does not appear to be a sharp seismic marker (Cornea 1964; Botezatu 1987).

In the Transylvanian Basin, seismic studies were concentrated on the Neogene seismic sequences as well as on the salt–Dej Tuff complex of Badenian age, these being two important seismic markers of the sedimentary layers (Ionescu *et al.* 1986). The areas of tectonic uplift of the crystalline basement show two other strong seismic horizons. These are the Mesozoic limestones and the sedimentary/basement boundary.

The Pannonian Depression is characterized by long correlatable reflections of Pannonian age. These are almost flat horizons in contrast to the pre-Pannonian seismic sequence. The interface between the sedimentary formations and the crystalline basement on the uplift areas shows a high seismic contrast (Ionescu 1981).

The Carpathian foredeep in front of the Carpathian orogen presents a succession of parallel reflection markers of Neogene age, with high velocity contrast.

GEOLOGICAL SETTING

Romania includes cratonic regions of pre-Alpine age (the Carpathian foreland) and Alpine orogenic areas of the Carpathians and the North Dobrudjan orogen (Fig. 1). The Carpathian mountain chain was formed by collision between the Variscan European continent and the microplates in front of the colliding African plate. The change in orientation of the Eastern Carpathians from a podolic to a Tethyan direction, and the bending of the Southern Carpathians with respect to the Balkan Mountains, produces pronounced curvatures.

The Carpathian orogen is bounded to the northeast by the pre-Vendian East European Platform (Moldavian Platform on the Romanian territory), and to the southeast and south by the Moesian Platform. The Transylvanian Depression is located inside the Carpathian arc, and the Pannonian Depression is partially developed on the western side of Romania.

The Moesian Platform is the Early Palaeozoic consolidated area which lies in the southern part of the Romania, and is boundade by the Peceneaga-Camena Fault (Fig. 1). Its basement is separated by the Intramoesian Fault into two distinct sectors: the Vallachian sector to the west and the Dobrudjan domain to the east (Sandulescu 1984). The Vallachian sector consists of Late Proterozoic mesometamorphic schists (Mutihac 1990), being pierced by Hercynian granitic, granodioritic and gabbroic intrusions (Paraschiv 1979). The southern side of the Dobrudjan sector is made up of Karelian metamorphosed rocks that extend from Southern Dobrudja to the west, between the Capidava-Ovidiu and Intramoesian faults (Visarion *et al.*, 1988). The northern part of this sector consists of greenschists metamorphosed in the Cadomian. They crop out in the central Dobrudja and extend westwards of the Danube, between the

From Wessely, G. & Liebl, W. (eds), 1996, *Oil and Gas in Alpidic Thrustbelts and Basins of Central and Eastern Europe*,
EAGE Special Publication No. 5, pp. 289–299.

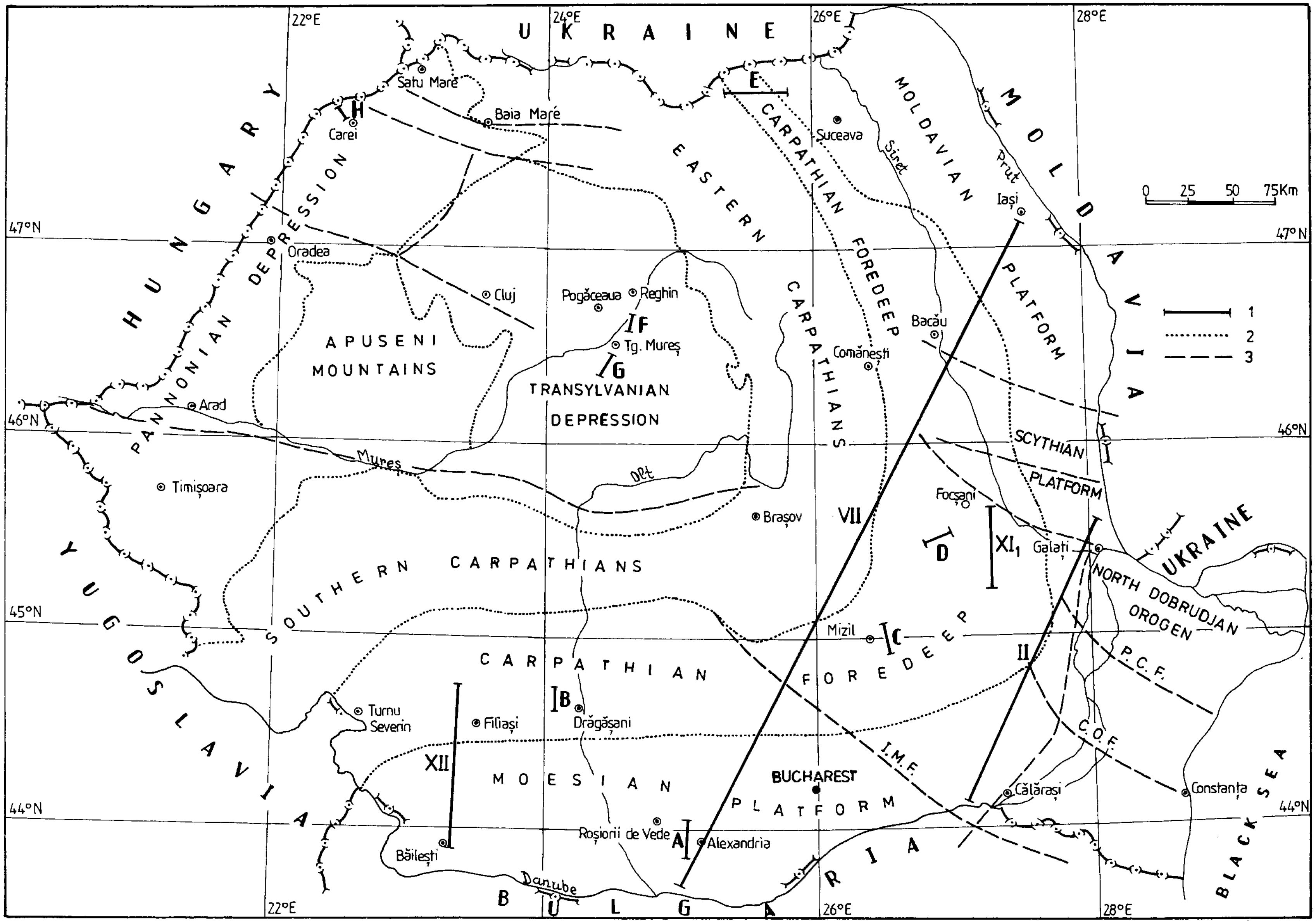

Fig. 1. Tectonic sketch map of Romania. 1, seismic line; 2, geological boundary; 3, crustal fault; P.C.F., Peceneaga-Camena Fault; C.O.F, Capidava-Ovidiu Fault; I.M.F, Intramoesian Fault.

Peceneaga-Camena and Capidava-Ovidiu faults (Visarion *et al.* 1988).

The sedimentary cover of the Moesian Platform begins with Cambrian(?) and Ordovician sediments and continues with some stratigraphic hiatuses up to the Neogene and Quaternary. This sedimentary cover is divided into four main seismic cycles: Ordovician–Carboniferous, Permian–Triassic, Jurassic–Cretaceous and Tertiary (Sandulescu 1984; Diaconescu *et al.* in press).

The Moldavian Platform represents the southwestern margin of the East European Platform. It contains a folded and metamorphosed crystalline basement of Karelian age, and a slightly faulted sedimentary cover with several cycles from the Vendian to the Pliocene, separated by some major stratigraphic discordances (Sandulescu 1984).

Between the Moldavian and Moesian platforms, two other small tectonic units have been identified: the Scythian Platform to the north, and the North Dobrudjan orogen to the south.

The Scythian Platform is a consolidated area of Early Palaeozoic age showing a crystalline basement consisting of metamorphic rocks deformed before the Carboniferous. The North Dobrudjan orogen is a Cimmeride–Early Alpine orogenic belt completely deformed before the Late Cretaceous.

The Transylvanian Basin is a molasse depression that overlaps the deformed elements of Alpine Europe. Its evolution began in the Neogene, and now it appears to be a post-tectogenetic unit. The Transylvanian basement consists of two distinct sequences (Ionescu *et al.* 1986):

- a lower sequence composed of folded and thrust elements (of crystalline formations, Mesozoic sedimentary folded formations and and pre-Tertiary volcanic rocks) which represent the prolongation of the Carpathian units below the depression
- an upper sequence belonging to the post-tectonic cover and consisting of Late Cretaceous–Tertiary formations.

The Transylvanian basement is marked by strong disjunctive tectonics subsequent to the Cretaceous tectogenesis, and which divides this unit into several blocks. Thus, the Pogaceaua uplift and the depression zone southwards of Tg. Mures are remarkable subunits, the latter containing a thick stack of Neogene sediments. At Pogaceaua, the top of the crystalline basement was reached at 2980 m by the well Pogaceaua 5. This uplift is also confirmed by gravity and air magnetic regional anomalies. The structure of the Transylvanian sedimentary cover is strongly influenced by the salt tectonics which created domes of 10–15 km diameter in the central part, and diapiric folds in the rim part of the depression with a N–S orientation.

The Pannonian Depression is largely developrd in Hungary but extends into the western side of Romania. It is a Neogene basin with a crystalline basement that crops out in the Apuseni Mountains and Southern Carpathians. The crystalline basement is made up of Palaeozoic metamorphic rocks that are pierced by acidic intrusions of various ages, from the Precambrian to the Palaeogene (Ionescu 1981). The sedimentary cover of the depression consists of two sequences: the lower one of pre-Neogene age, and an upper sequence of Neogene molasse.

SEISMIC DATA

The large number of reflection and refraction seismic lines recorded in Romania have identified several specific characteristics of the major tectonic provinces. The variability in the reflectivity patterns and crustal thicknesses of the different tectonic units is due to the differences in lithology and seismic characteristics, as well as to differences in crustal age.

Moesian platform

The sedimentary cover of the Moesian Platform shows three strong seismic markers with characteristic reflections, correlatable over great distances. They result from lithological horizons of high velocity contrasts (Burcea *et al.* 1966). These horizons are as follows:

(a) the Neogene–Cretaceous boundary which generates prominent reflections, with reflection coefficients up to 0.36,

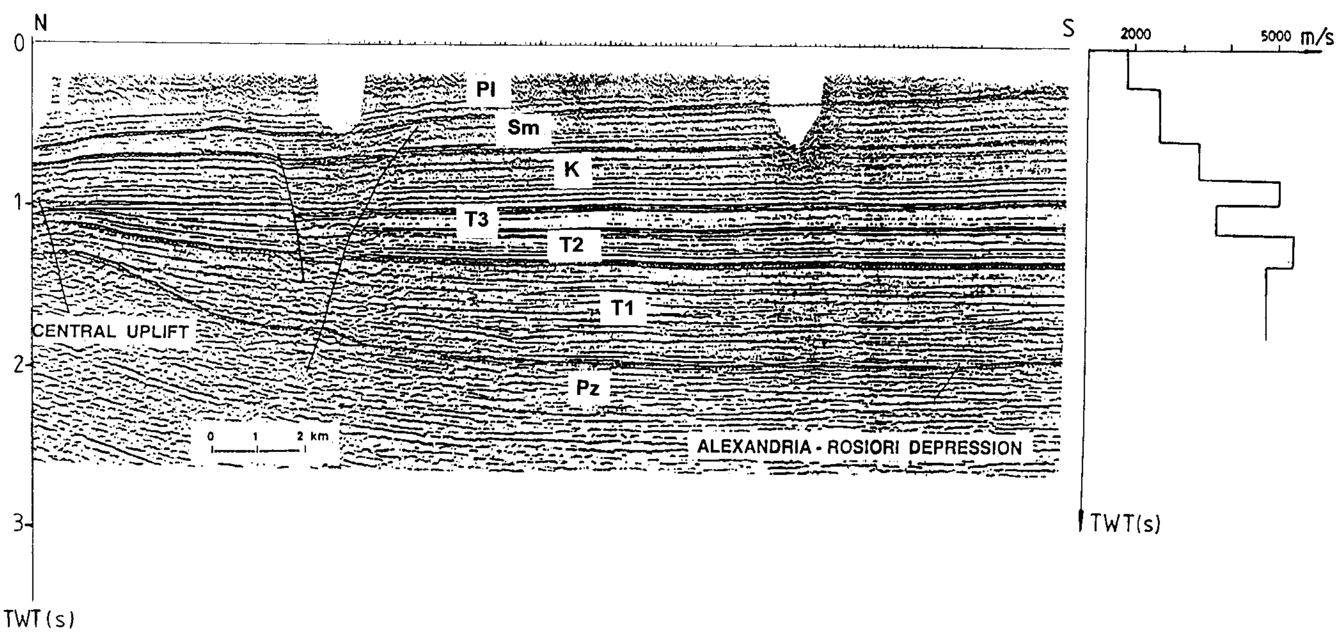

Fig. 2. Seismic section of line A (Alexandria–Rosiori depression) and interval velocity-depth function. Pl, Pliocene; Sm, Sarmatian; K, Cretaceous; T3, Upper Triassic; T2, Middle Triassic; T1, Lower Triassic; Pz, Palaeozoic.

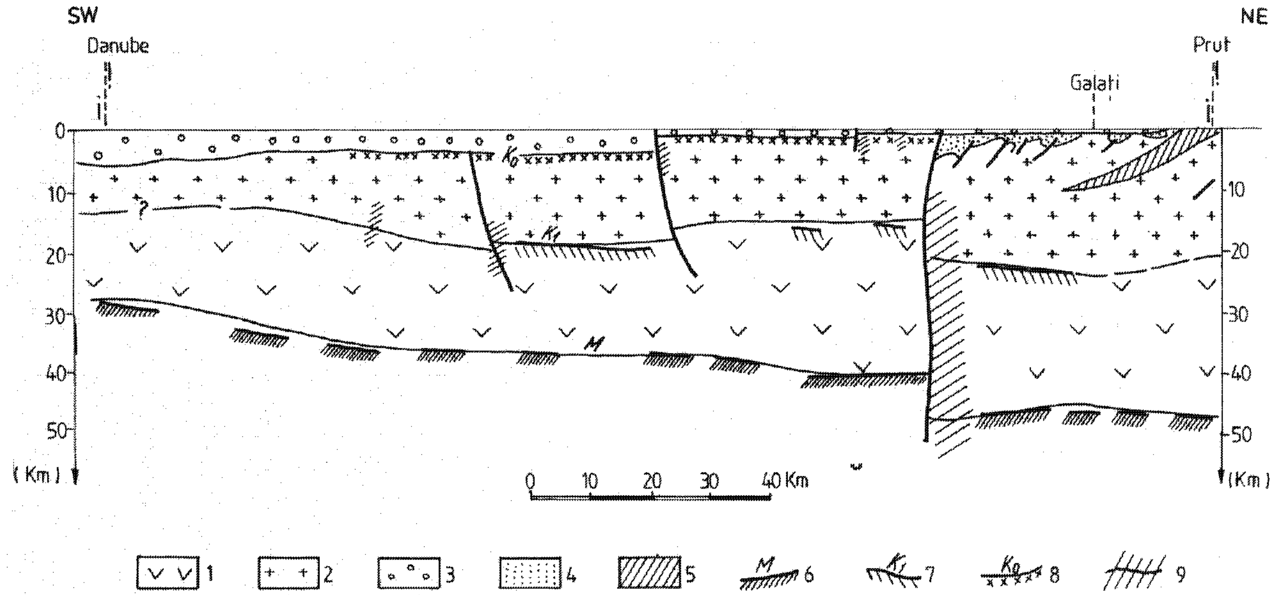

Fig. 3. Seismotectonic section of the Galati–Calarasi profile-II in Fig. 1. 1, lower crust; 2, upper crust; 3, sedimentary cover; 4, Mesozoic and Palaeozoic deposits of Macin and Tulcea units; 5, Niculitel unit; 6, Moho; 7, Conrad; 8, Basement surface; 9, crustal fault.

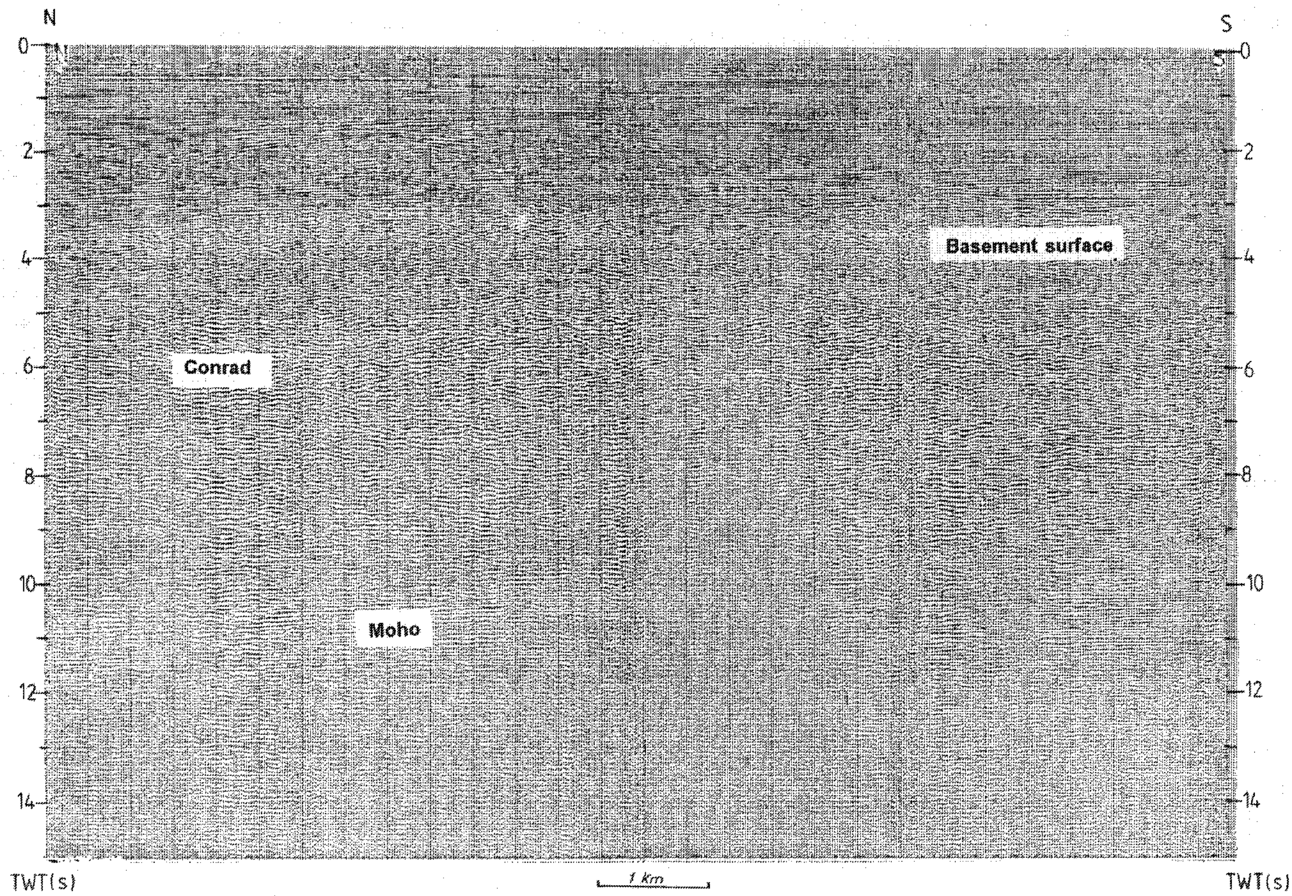

Fig. 4. Seismic section of line B, the Dragasani zone.

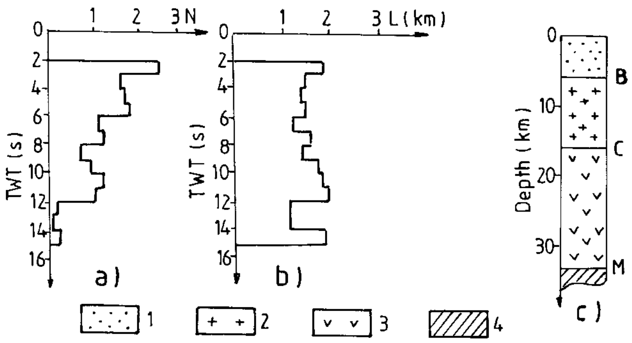

Fig. 5. Reflectivity histograms of line B, the Dragasani zone. (**a**) histogram with reflectivity density; (**b**) histogram of average length of reflections; (**c**) simplified crustal model. 1, sedimentary cover; 2, upper crust; 3, lower crust; 4, upper mantle.

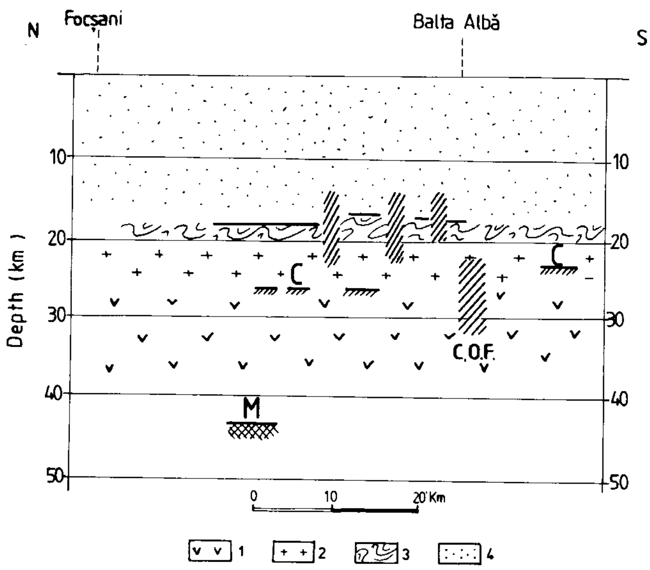

Fig. 6. Seismic refraction section on line XI_1, the Focsani Depression. 1, lower crust; 2, upper crust; 3, crystalline basement; 4, sedimentary cover; C, Conrad; M, Moho; C.O.F., Capidava–Ovidiu Fault.

that appear at ~ 6.0–6.5 s TWT (two-way travel-time) in the northern side of the Platform (with a thick sedimentary cover), and at ~ 0.3 s TWT to the south (on the uplift zones);

(b) the Malm–Dogger interface, wich has an important velocity contrast;

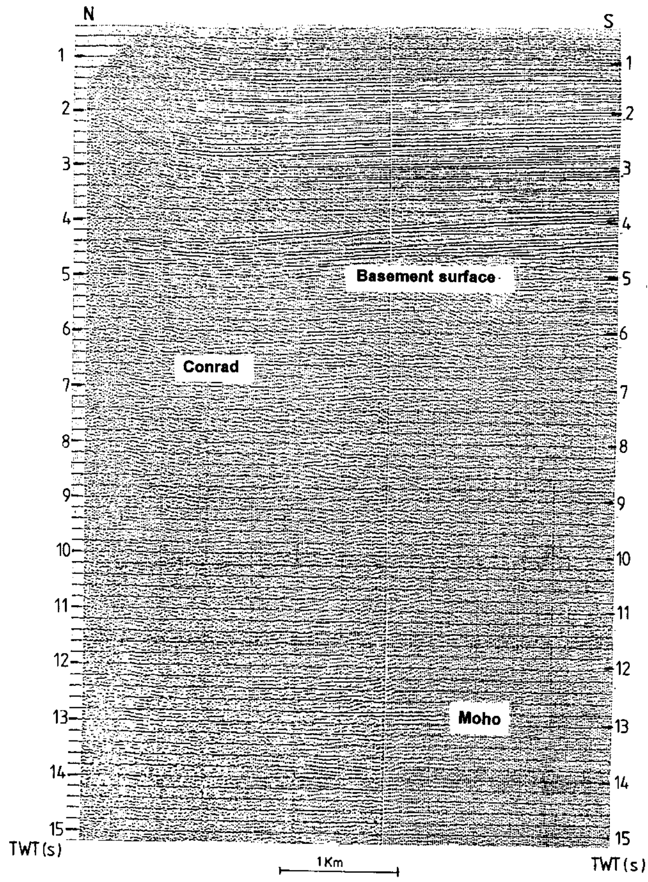

Fig. 7. Seismic section of line C, the Mizil zone.

(c) the Upper–Lower Triassic limit, representing the top of the limestones and dolomites, with a high contrast of acoustic impedance.

Within the Neogene section, an alternation of sands and gravels with marls, sandstones and limestones generate strong contrasts in acoustic impedance. Several important interfaces are: the Dacian sands–Pontian marls, the Meotian sandstones, and the calcareous sandstones and marls from the base of the Sarmatian, which show a reflection coefficient of 0.47 near Bucharest. Below the Neogene cover, the top of the Cretaceous limestones generates a prominent reflection with reflection coefficients of 0.32–0.34 (Paraschiv 1979). The refraction lines recorded

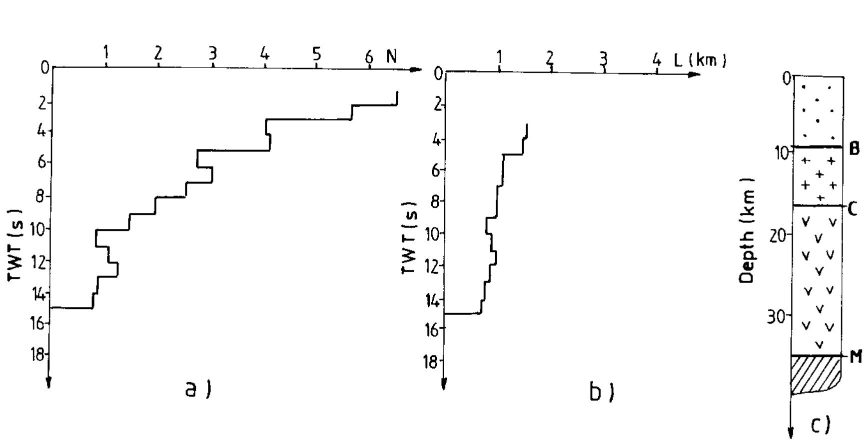

Fig. 8. Reflectivity histograms of line C, Mizil zone. (**a**) histogram of reflectivity density; (**b**) histogram of average length of reflections; (**c**) simplified crustal model. For key, see Fig.5.

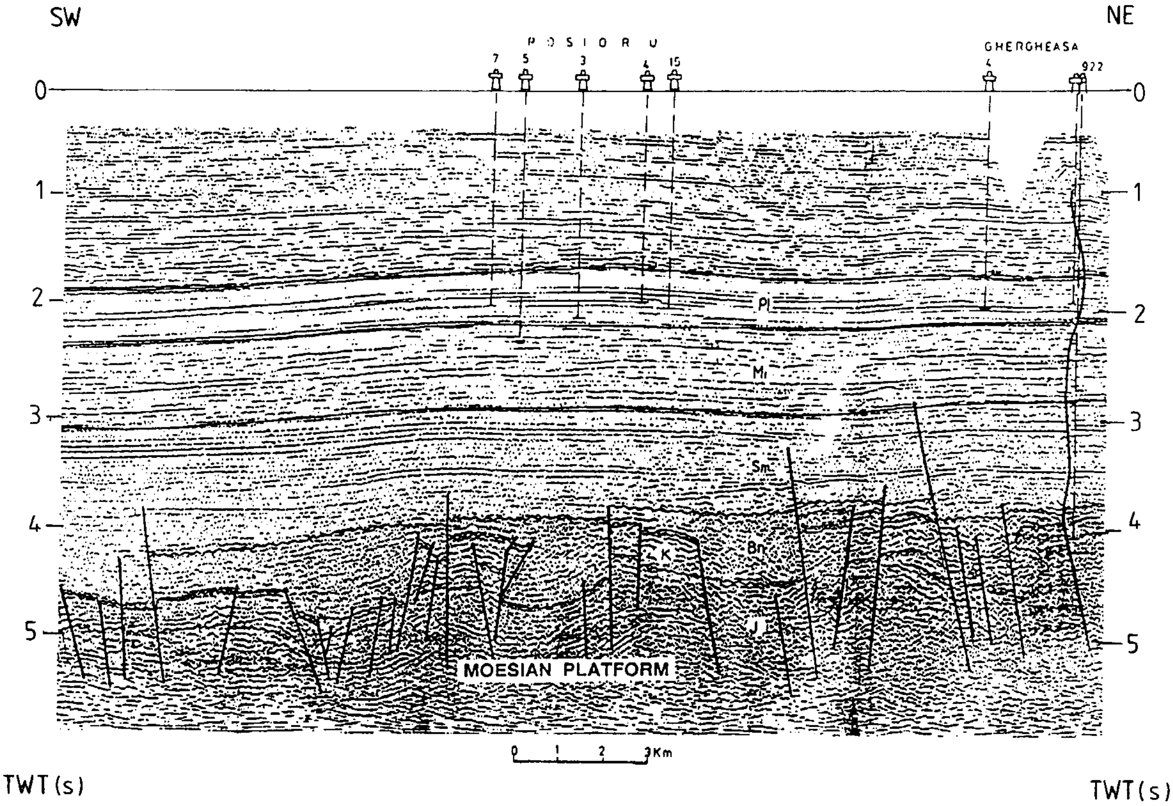

Fig. 9. Seismic section of line D, the Focsani zone. Pl, Pliocene; Mi, Miocene; Sm, Sarmatian; Bn, Badenian; K, Cretaceous; J, Jurassic.

westwards of the Intramoesian Fault demonstrate strong head waves from this horizon with a high velocity contrast. Generally, the Neogene sequence shows horizontal reflections correlatable over a great distance, while the Mesozoic section is characterized by shorter and dipping reflections with high amplitude variation. Several seismic lines with more than 24-fold coverage show some correlatable reflections from the top of the Palaeozoic limestones and even from the sedimentary–basement boundary (Varodin *et al.* 1968).

Figure 2 shows a seismic line recorded in the central part of the Moesian Platform, westwards of the Intramoesian Fault, in the region of greatest subsidence, the Rosiori–Alexandria depression (line A in Fig. 1). The almost flat reflections of the Neogene are visible in comparison with the deeper layers of the Mesozoic and Palaeozoic ages. Fracture of the sedimentary cover is shown by a few faults that produced uplift and depression structures.

The top of the crystalline basement has mostly been investigated by deep seismic soundings. Deep seismic refraction lines across the Moesian Platform (Galati-Calarasi, II;- Filiasi Bailesti, XII) distinguished head waves from the basement surface, with layer velocities of 5.8–6.4 km s^{-1} (Radulescu 1981). A mid-crustal layer, supposedly the Conrad Discontinuity, has been identified, with a velocity of 6.5–7.0 km s^{-1}, in the western side of the Moesian Platform (Constantinescu *et al.* 1970; Cornea *et al.* 1981).

The Galati–Calarasi refraction profile (profile II, Fig.1) demonstrated a thinning of the crust from the north (46–47 km thick in the Galati zone) to the south (30–31 km thick near the Danube) (Radulescu 1979). A deep fracture with a throw of 7–8 km at the Moho, and of 5–6 km at the Conrad Discontinuity (Fig. 3), was seen south of Galati. It represents the prolongation of the Peceneaga–Camena Fault, from the Dobrudja.

The deep seismic reflection lines recorded on the Moesian Platform found some important differences in the reflectivity pattern from the west to the east and northeast. The western sector of the Moesian Platform shows a relatively transparent upper crust and a layered lower crust, with strong bands of reflections around the crust–mantle transition zone, at ~ 9.5–11.5 s TWT. The central and eastern parts show decreasing reflectivity with depth, and the Moho is poorly distinguished (Raileanu *et al.* 1994).

Carpathian foredeep

The Carpathian foredeep is characterized by predominantly Neogene sedimentary rocks, largely derived from the Carpathians, but also with a significant contribution of detritus from the more external Moldavian and Moesian platforms. The foredeep ranges in width from only a few kilometres (~ 10 km) in the northern part of the Eastern Carpathians, to more than 100 km at the Southern Carpathian bend. The greatest thickness of the foredeep sediments is south of the Eastern Carpathian bend in the Focsani Depression, where the Neogene rocks are probably 8 to 10 km thick (Sandulescu, 1984). Recent crustal movements characterize areas of active subsidence (up to 3 mm yr^{-1}) in this zone (Popescu & Dragoescu 1987).

Figure 4 shows a deep seismic line from the central side of the Southern Carpathian foredeep, near Dragasani (line B in Fig. 1). This line was recorded down to 15 s TWT and shows a very reflective sedimentary cover down to 3.5–4.0 s TWT. The top of the crystalline basement does not generate characteristic reflections, but it was interpreted at ~ 4.0 s TWT (6–7 km depth) (Barbu 1980).

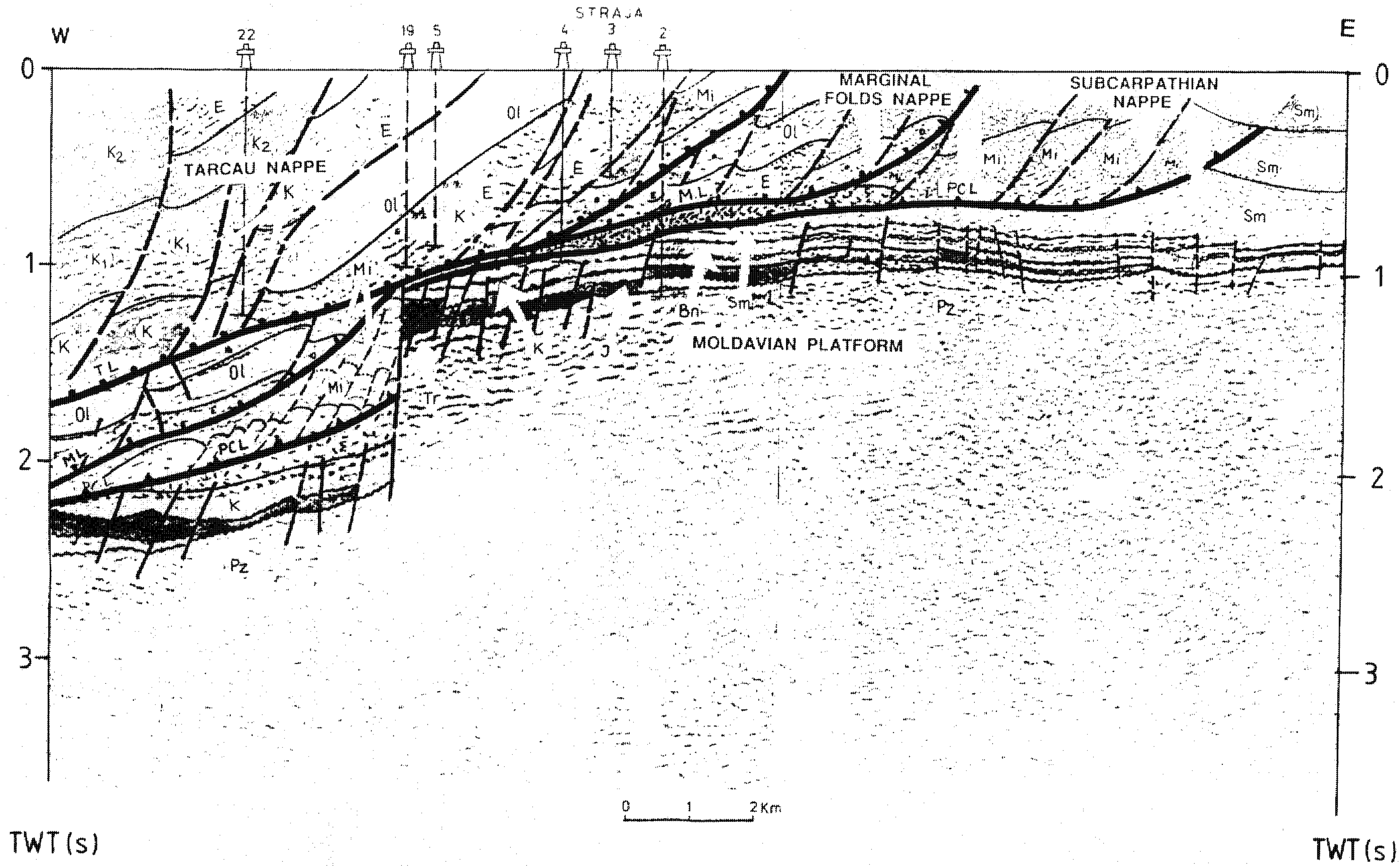

Fig. 10. Geological model on the seismic section of line E (Moldavian Platform. Sm, Sarmatian; Mi, Miocene; Ol, Oligocene; E, Eocene; Bn, Badenian; K, Cretaceous; K_1, Lower Cretaceous; K_2, Upper Cretaceous; J, Jurassic; Tr, Triassic; Pz, Palaeozoic; PCL, Pericarpathian line.

The upper crust consists of many short and dipping events. The reflectivity decreases with depth, and the Moho appears to be indicated by some long correlatable reflections at 10.5–11.6 s TWT. Some reflectivity analyses of this reflection line are shown in Fig. 5. Where we present histograms of the density of reflections and the average length of reflections (Wever *et al.* 1987; Raileanu *et al.* 1994). A simplified crustal model in this area is presented in Fig. 5c. The reflectivity pattern of this line is in accordance with the low surface heat flow in this region of ~ 40 mW m^{-2} (Demetrescu & Andreescu 1994).

A deep seismic refraction line recorded in front of the Eastern Carpathian arc bend zone (XI_1) showed a thick sedimentary cover (17–18) km in the Focsani Depression (Fig. 6). The Conrad Discontinuity was interpreted at 24–26 km depth, and the Moho at ~ 43–44 km. A deep fault with ~ 5 km throw at the Conrad level was identified in the southern part of the line. It is considered to be the prolongation of the Capidava–Ovidiu Fault that extends from the central Dobrudja to the northwest (Fig. 1). The sedimentary–basement surface shows a layer velocity of 6.5 km s^{-1}, corresponding to the great depth of this seismic marker (Radulescu 1979). Figure 7 shows a deep seismic reflection section recorded in the same region, near Mizil (line C in Fig. 1). The top of the basement was considered to be at ~ 5.0 s TWT. Reflections from 6.2–6.8 s TWT may represent the transition zone between the upper and lower crust, and the Moho is shown by the strong and correlatable reflections from 12.8–13.0 s TWT. The reflection horizons dip slightly from the south to the north, following the tilt of the foredeep deposits towards the orogen. The reflectivity analyses of this line are presented in Fig. 8.

The seismic line in Fig. 9 (line D in Fig. 1) illustrates the undisturbed Neogene deposits of the Carpathian foredeep that overlie the fractured Mesozoic layers of the Moesian Platform.

Moldavian Platform

The Badenian anhydrite forms a strong seismic marker within the sedimentary cover of the Moldavian Platform (Botezatu 1987). The seismic sequence below the anhydrite is characterized by poor reflectivity. The layers above the Badenian anhydrite show strong and correlatable reflections.

The contact between the sedimentary deposits and the crystalline basement and the top of the Palaeozoic limestones generates reflected and head waves (Cornea 1964).

A deep NE–SW oriented seismic refraction line (VII) across the Moldavian and Moesian platforms (Fig. 1) identifies the base of crust at ~ 40–44 km depth, in the Iasi–Bacau zone (Pompilian *et al.* 1991).

Figure 10 shows a seismic line across the contact between the Moldavian Platform and the outer flysch of the Eastern Carpathians (line E in Fig. 1). The top of the Palaeozoic deposits dips slightly from east to west, following the general thickening of the Platform cover towards the orogen.

Transylvanian Depression

From the seismic viewpoint, the sedimentary cover of the Transylvanian Depression is divided into two distinct sequences by the salt–Dej Tuff horizon, as follows: a lower sequence

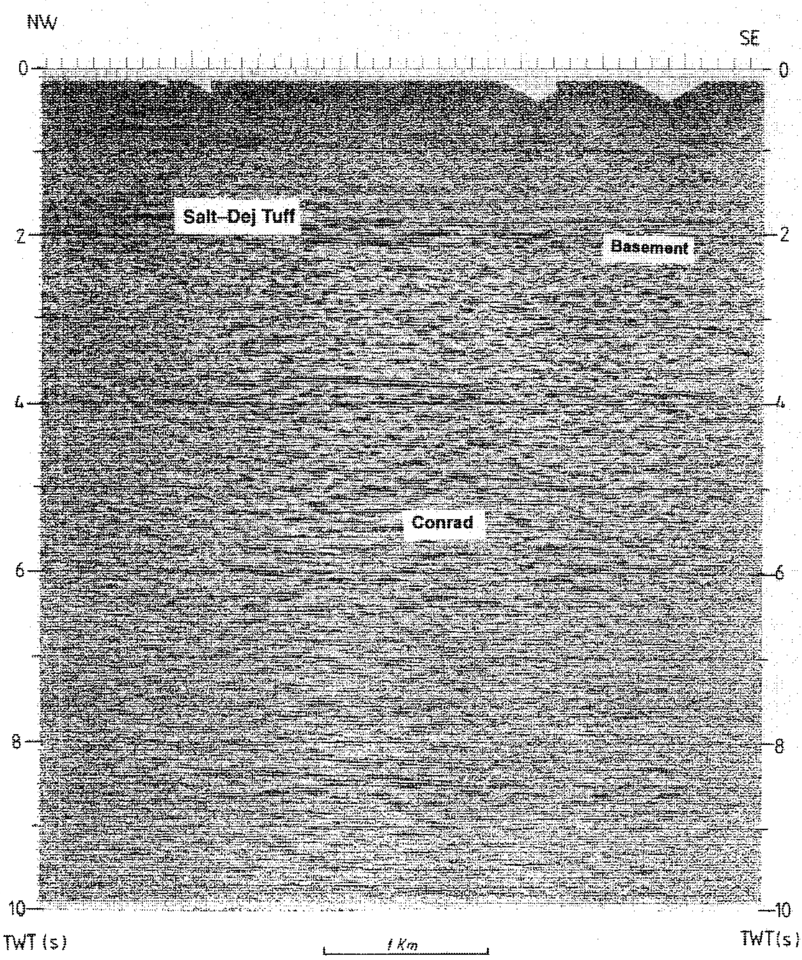

Fig. 11. Seismic section of line F, north Tg. Mures.

corresponding to the pre-Badenian deposits, and presenting only several short reflections; and the upper sequence, of Neogene age, showing prominent reflections of high frequencies.

Two deep seismic reflection lines have been performed in the central side of the basin, one in the northern part and the other in the southwestern part of Tg. Mures city (lines F and G in Fig. 1).

The seismic reflection line F with a NW–SE orientation is located between the uplift area of Pogaceaua and the depression region of Reghin. The seismic section shows a strong reflective horizon at 1.8 s TWT, that was attributed to the salt–Dej Tuff complex (Fig. 11). The prominent reflection from 2.0 s TWT was interpreted to be the crystalline basement surface. The strong reflective zone from 5.0–5.5 s TWT marks the transition zone between the upper and lower crust. With an average velocity of 5.0 km s^{-1} (Fig. 12), the depth of this horizon was interpreted to lie at 13 km. The seismic reflections at 6.4–6.5 s and 8.4–8.5 s TWT belong to the lower crust. These intense reflections suggest the nappe structure of the Transylvanian basement. The reflectivity analyses of this line are shown in Fig. 13. The reflectivity pattern of this line is evidence of a ductile medium in the lower crust agreeing with the high temperatures at 20 km depth of 400 °C (Demetrescu & Andreescu 1994). Unfortunately, the Moho is not shown by this line because it is below 10 s TWT.

The deep seismic reflection line G shows the salt–Dej Tuff layer at 2.1 s TWT on the northern side, and at 2.5 s TWT to the south (Fig. 14). The Mesozoic deposits lie in the 3.0–3.1 s TWT interval. The top of the crystalline basement was interpreted between 3.7 and 4.2 s TWT. This line is characterized by a strongly reflective sedimentary cover, with many lengthy reflections. The basement surface is shown by some pronounced reflections interrupted by deep fault zones. These reflections are horizontal on the southern side, and they start to dip slightly towards the north. The reflectivity histograms in Fig. 15 show a decreasing reflectivity with depth in the upper crust. The length of reflections varying between 1 and 2 km, in accordance with the relatively low temperature at 20 km depth of ~ 300 °C (Demetrescu & Andreescu 1994). The top of the lower crust at 6–7 s TWT is marked by a slight increase in the reflectivity.The base of the seismic time section ends at the lower crustal level; the Moho is not reached.

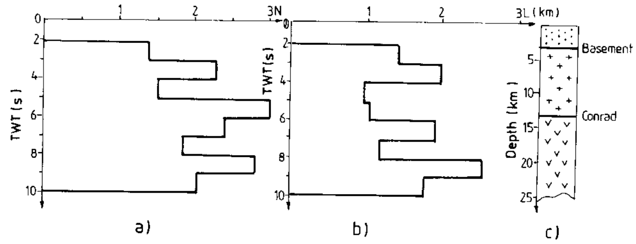

Fig. 13. Reflectivity histograms of line F, north Tg. Mures. (**a**) histogram of reflectivity density; (**b**) histogram of average length of reflections; (**c**) simplified crustal model. For key, see Fig.5.

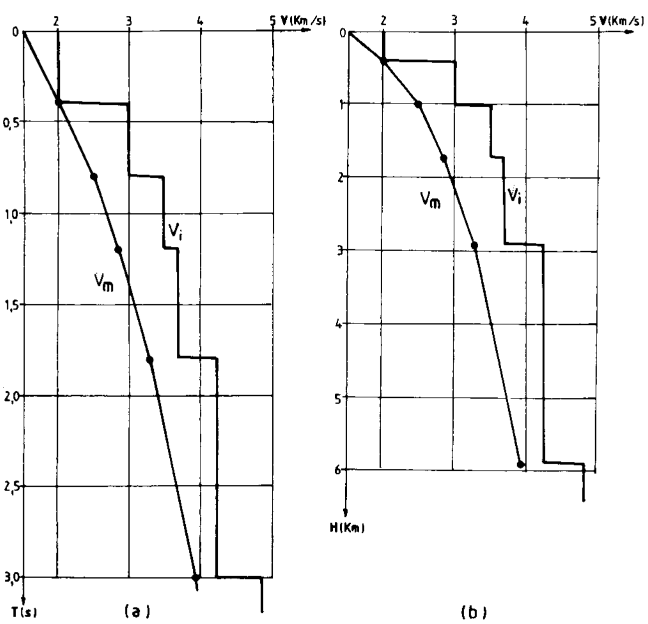

Fig. 12. (**a**) Average velocity (V_m) vs. time and (**b**) interval velocity (V_i) vs. depth in the Transylvanian Depression.

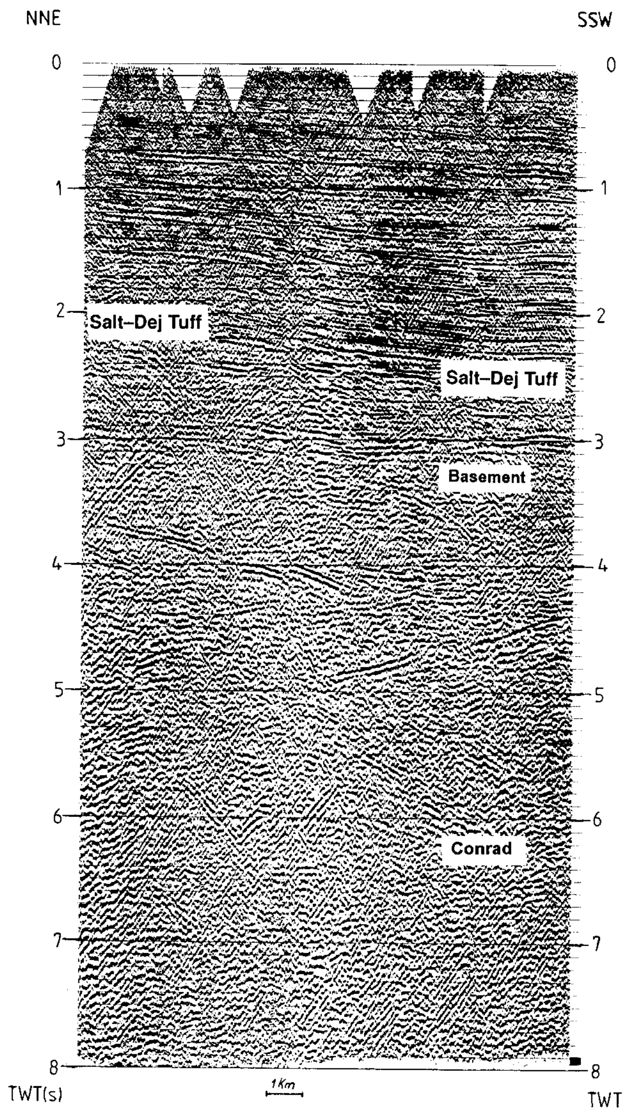

Fig. 14. Seismic section of line G, south Tg. Mures.

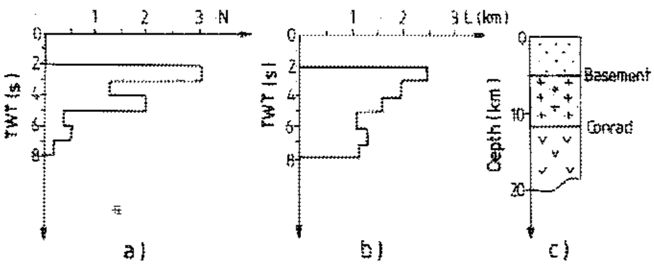

Fig. 15. Reflectivity histograms of line G, south Tg. Mures. (**a**) histogram of reflectivity density; (**b**) histogram with average length of reflections; (**c**) simplified crustal model. For key, see Fig.5.

Pannonian Depression

The Pannonian Depression has been thoroughly investigated by seismics because of its great potential for oil. The seismic lines recorded in this region show distinctive reflectivity patterns for the Pliocene and pre-Pliocene layers. While the reflective horizons belonging to the Pliocene are readily correlated over a distance, the pre-Pliocene layers show only a few short reflections, evidence of the highly tectonized regime of these formations.

The crystalline basement surface was only identified on the seismic sections acquiried in the uplifted areas, where the Pliocene deposits directly overlie the basement (Ionescu 1967, 1979).

The sedimentary cover of the Pannonian Depression presents some specific seismogeological sequences which vary from one region to another. Thus, four main seismic sequences were separated in the Arad zone (Fig. 1): the Miocene sequence (1), with high amplitude and low frequency reflections, which overlies discordantly the crystalline basement, the Lower Pannonian (2), the Middle Pannonian (3) and the Upper Pannonian (4) (Botezatu 1987).

Other seismogeological markers specific to the Pannonian Depression are: the surface of the Cretaceous limestones (Oradea zone), the base of the Pannonian deposits (north Oradea), and the Sarmatian–Badenian boundary (Satu Mare region).

A deep seismic reflection line recorded in the Carei zone (line H in Fig. 1) shows a reflective sedimentary cover down to 2.0–2.2 s TWT and a relatively transparent crust, crossed by some short and dipping events, down to 8.6–9.0 s TWT, that represent the transition from the crust to the uppermost mantle (26–28 km depth) (Fig. 16).

CONCLUSIONS

Seismic reflection and refraction profiling in Romania has discovered some strong seismic markers in the sedimentary cover of the platforms, as a result of the high contrast in acoustic impedance between the geological layers. These horizons are very important for their correlation with several hydrocarbon-bearing structural units.

Sand and gravel formations (with low velocities) as well as marls, sandstones and limestones (with high velocities) are strong seismic reflective horizons with high amplitude and are easy to correlate over a distance. Of these formations, the Lower Sarmatian section, composed of calcareous sandstones and hard limestones, presents high reflection coefficients and can be traced over extensive areas of the Moesian Platform. This seismic marker separates the Upper Neogene sequence, with almost horizontal reflections (evidence of a quiescent sedimentary process), from the lower sequence of Mesozoic–Palaeozoic age, which shows dipping and discontinuous reflections. A similar character is shown by the Pannonian–pre-Pannonian boundary in the Pannonian Depression, and by the salt–Dej Tuff geological complex from the Transylvanian Depression.

The deeper sedimentary cover of the Moesian Platform contains prominent reflections from the Cretaceous and Jurassic calcareous beds and from the Triassic dolomites, as well as from the Palaeozoic limestones.

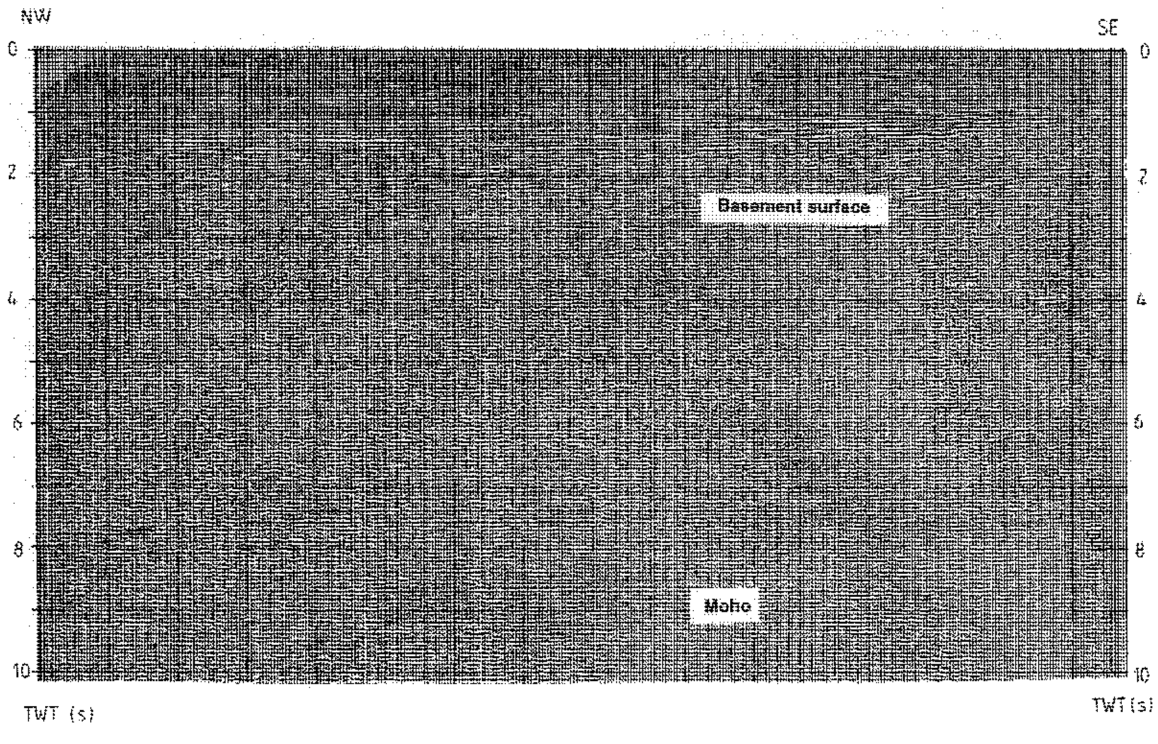

Fig. 16. Seismic section of line H, the Carei zone (Pannonian Depression).

The surface of the crystalline basement is poorly marked on the seismic reflection profiling over the Moesian platform. The deep seismic refraction lines (II, VII, XI, XI_1 and XII in Fig. 1) recorded head waves from the crystalline basement surface. The sedimentary–basement boundary was also identified on the Moldavian Platform and in the Transylvanian and Pannonian depressions, but only on the uplifted blocks (Ionescu 1967, 1981).

Some seismic characteristics were identified in the deep crust. The transition from the upper to the lower crust was marked on most of reflection and refraction lines as an interval that passes from a transparent upper crust to a reflective lower crust, or as head waves with velocities of ~ 7.0 km s^{-1} (see lines II and XII in the Moesian platform, line XI_1 in the Carpathian foredeep, and line XI in the Transylvanian Depression). The crust–mantle boundary appears as a transition zone of a thickness of 2–3 s TWT on the seismic reflection lines, or 3–5 km thick on the refraction profiles, rather than as a sharp boundary. It lies at 30–35 km depth in the Moesian platform, 33–45 km depth in the Moldavian Platform, 28–34 km in the Transylvanian Depression, and 26–29 km in the Pannonian Depression. The deepest Moho in Romania is encountered in the Carpathian foredeep, in front the Carpathian arc bend zone, where it lies at a depth of around 52 km.

The authors are grateful to G. Wessely for special support in attending the EAPG meeting in Vienna (1994). We acknowledge both editors and an anonymous reviewer for improving the final version of our paper.

REFERENCES

BARBU, C. 1980. The tectonics of the crystalline basement. *Mine. Petr. Gaze*, **3**, 492–501 (in Romanian).

BOTEZATU, R. 1987. *Bases of the Geological Interpretation from Geophysical Information.* Technical Publishing House, Bucharest (in Romanian).

BURCEA, C., CORNEA, I., TUGUI, GR., TOMESCU, L., IONESCU, E., TRAMBITAS, M., LEAFU, I., DUMITRESCU, V., BRASOVEANU, A. & SIPOS, V. 1966. Contributions of seismic reflection to create a tectonic image in the central part of the Moesian platform. *Studii şi Cercetări de Geologie, Geofizică, Geografie, Seria Geofizică*, **4**, 347–354 (in Romanian)

CONSTANTINESCU, P., CORNEA, I., ENESCU, D., PATRUT, ST., RADULESCU, F. & SPANOCHE, S. 1970. Preliminary evaluations of the crust thickness on the Romanian territory. *Revue Roumaine de Geologie, Geophysique et Geographie, Series Geophysique*, **14**, 3–14 (in French).

CORNEA, I. 1964. Geophysical contributions to the study of geological structure of the Barlad depression. *Studii şi Cercetări de Geologie, Geofizică, Geografie, Seria Geofizică*, **2**, 83–113 (in Romanian).

——— & LAZARESCU, V. 1980. *Tectonics and Geodynamic Evolution of the Romanian Territory.* Central Institute of Physics, Bucharest-Magurele (in Romanian).

———, RADULESCU, F., POMPILIAN, A. & SOVA, A. 1981. Deep seismic sounding in Romania. *Pageof*, **119**, 1144–1156.

DEMETRESCU, C. & ANDREESCU, M. 1994. On the thermal regime of some tectonic units in a continental collision environment in Romania. *Tectonophysics*, **230**, 265–275.

DIACONESCU, M., RADULESCU, F., DIACONESCU, C., BITER, M. & POMPILIAN, A. Crustal information from seismic and gravity data in the Moesian Platform and Carpathian foredeep (Romania). *Romanian Reprints in Physics* (in print).

DUMITRESCU, I. & SANDULESCU, M. 1970. *Tectonic Map of Romania, 1 : 1,000,000.* Institute of Geology, Romania.

IONESCU, N. 1967. Study of the Pannonian Depression from seismic prospections. *8th Congr. of Assoc. Geol. Carpato-Balk., Beograde.*

——— 1979. Scientific research of paleoreliefs from seismic studies. *Revue Roumaine de Geologie, Geophysique et Geographie, Series Geophysique*, **23**, 93–116.

——— 1981. *Conditions of the Hydrocarbon Accumulations in Lithostratigraphic Traps and the Possibilities of the Seismometry in Prospecting the Deposits of this type on Continental Shelves, with Special View to Banat (Romania).* PhD Thesis, University of Bucharest, Faculty of Geology and Geography (in Romanian).

———, POLONIC, P. & TEODORESCU, V. 1986. Structure and morphology of the Transylvanian depression according to some geophysical data. *Studii şi Cercetări de Geologie, Geofizică, Geografie, Seria Geofizică*, **24**, 17–24 (in Romanian).

MUTIHAC, V. 1990. *Geological Structure of the Romanian Territory.* Technical Publishing House, Bucharest (in Romanian).

PARASCHIV, D. 1979. *The Moesian Platform and its Hydrocarbon Deposits.* Acad. Publishing House, Bucharest (in Romanian).

POMPILIAN, A., RADULESCU, F. & BITER, M. 1991. Some results of deep seismic soundings in the south–western part of the East European platform. *Studii şi Cercetări in Fizică*, **43**, 271–278 (in Romanian).

POPESCU, M. N. & DRAGOESCU, I. 1987. Maps of recent vertical crustal movements in Romania: similarities and differences. *Journal of Geodynamics*, **8**, 123–136.

RADULESCU, F. 1979. *Seismic Studies on the Crustal Structure in Romania.* PhD Thesis, University of Buharest, Faculty of Geology and Geophysics (in Romanian).

——— 1981. Crustal seismic studies in Romania. *Revue Roumaine de Geologie, Geophysique et Geographie, Series Geophysique*, **25**, 57–74.

RAILEANU, V., DIACONESCU, C. & RADULESCU, F. 1994. Characteristics of Romanian lithosphere from deep seismic reflection profiling. *Tectonophysics*, **239**, 165–185.

SANDULESCU, M. 1984. *Geotectonics of Romania.* Technical Publishing House, Bucharest (in Romanian).

VARODIN, V., BADESCU, L., CHISCAN, V., CHISCAN, M., CALOINESCU, G., IONESCU, G., POPESCU, A., TRANCA, M. & TUGUI, Gr. 1968. On the possibility to obtain geological information from deep boundaries by seismic reflection method. *Studii şi Cercetări de Geologie, Geofizică, Geografie, Seria Geofizică*, **6**, 243–262 (in Romanian).

VISARION, M., SANDULESCU, M., STANICA, D. & VELICIU, S. 1988. Contributions to the knowledge of the Moesian Platform deep structure. *Studii Tehnice şi Economice, Seria D*, **15**, 211–222.

WEVER, T., TRAPPE, H. & MEISSNER, R. 1987. Possible relations between crustal reflectivity, crustal age, heat flow, and viscosity of the continents. Annals of Geophysics, **5B**, 255–266.