SOME PROBLEMS ON EARTHCRUST STRUCTURE IN ALBANIA

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A B S T R A C T

Based on first onsets of P waves from moderate earthquakes foci and big explosions, in Albania and surrounding areas, some conclusions on Earth Crust structure in Albania and in Western Balkans are presented, considering P waves as head waves and refracted- reflected ones. It is shown that the nature of Earth Crust is rather complicated from more deeper structure at the east to shallower one versus Adriatic Sea. An attempt is made for Moho discontinuity mapping for Western Balkans.

ΜΕΛΕΤΗ ΤΩΝ ΠΡΟΒΛΗΜΑΤΩΝ ΤΗΣ ΔΟΜΗΣ ΤΟΥ ΦΛΟΙΟΥ ΣΤΗΝ ΑΛΒΑΝΙΑ

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Π Ε Ρ Ι Λ Η Ψ Η

Με βάση τις πρώτες αναγραφές των κυμάτων P από σεισμούς ενδιαμέσου βάθους και μεγάλες τεχνητές εκρήξεις, στην Αλβανία και στις γύρω περιοχές, καταλήξαμε σε συμπεράσματα, για την δομή του φλόιού της Γης, τόσο για την Αλβανία όσο και γενικότερα για την δυτική πλευρά των Βαλκανίων, τα οποία και παρουσιάζονται στην παρούσα εργασία. Για τον σκοπό αυτό μετρήθηκαν οι πρώτες αναγραφές τόσο των απευθείας κυμάτων P, όσο και εκείνες του διαθλώμενων και ανακλώμενων. Δείχθηκε οτι η δομή του φλοιού είναι αρκετά πιό πολύπλοκη από αυτήν των βαθυτέρων στρωμάτων στα ανατολικά ενώ το αντίθετο παρατηρείται για τις δομές που βρίσκονται προς την Αδριατική. Τέλος γίνεται μιά προσπάθεια να χαρτογραφηθεί το βάθος της ασυνέχειας Moho για την δυτική πλευρά των Βαλκανίων.

INTRODUCTION

There are a lot of methods concerning determination of **v(h)** functions through the interpretation of hodochrones of the first onsets of P waves generated by earthquakes or big explosions recorded in seismological stations. It's due to the fact that the information of first onsets of P waves is not influenced by subjective judgment and due to new developments of their theory and practice.

Methods used for the determination of v(h) functions using hodochrones of the first onsets of P waves:

To avoid uncertainity of data , reducted hodochrones had been used (Kociaj, 1985):

$$tr = t - \frac{\Delta}{6} \quad (1)$$

where: tr- reducted time

t- time of P onsets

D- epicentral distance

From these hodochrones following picture can be seen after their smoothing by cubic spline or finite element procedures (Kociaj 1986, Pitarka 1986, see fig.1.):

Direct Pg phase is shown (figure 1b) as convex segment, Pn phase as linear segment with negative time intercept, Pm phase as concave segment.

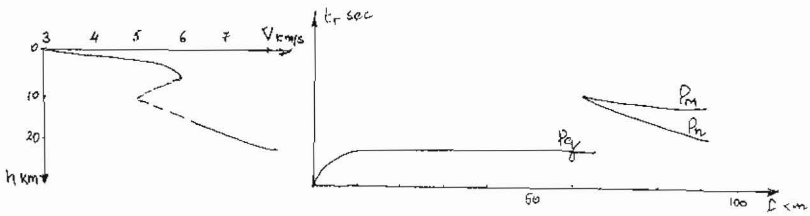

Fig.1. Pg,Pm,Pn hodochrones (b) for a Earth Crust section with velocity inversion (a).

1.1. The first onsets of P waves as head waves:

Based on this kind of interpretation the determination of v(h) functions was made based on the inversion of τ(p) parameter, according to the relation (Diebold and Stoffa 1981):

$$\tau(p) = T(p) - pX(p) \quad (2)$$

Based on τ(p) values the hodochrones of head waves for multilayered medium can be computed(Burmin 1981):

$$t_{ik} = \tau(p_k) + p_k D_i \quad (3)$$

t is well known that X(p) and T(p) functions are very sensitive to p parameter values. So it was observed that X(p) is more sensitive to p changes than τ(p). From the figure 2, it can be seen that for different step intervals (every 3, 5 , 7 points) the response of X(p) is more sensitive than that one of (p).

1.1.1. The determination of τ(p) :

For the determination of τ(p) function the procedure proposed by Dorman and Jacobson,(1981) was accepted. It was observed that the best solutions were achieved for intervals of 5 km in epicentral distances and for steps every 3-7 points.

1.1.2. Inversion of τ(p) :

The inversion of τ(p) was made using summation method, similar to intercept method, using a recursive formula (Diebold and Stoffa 1981).

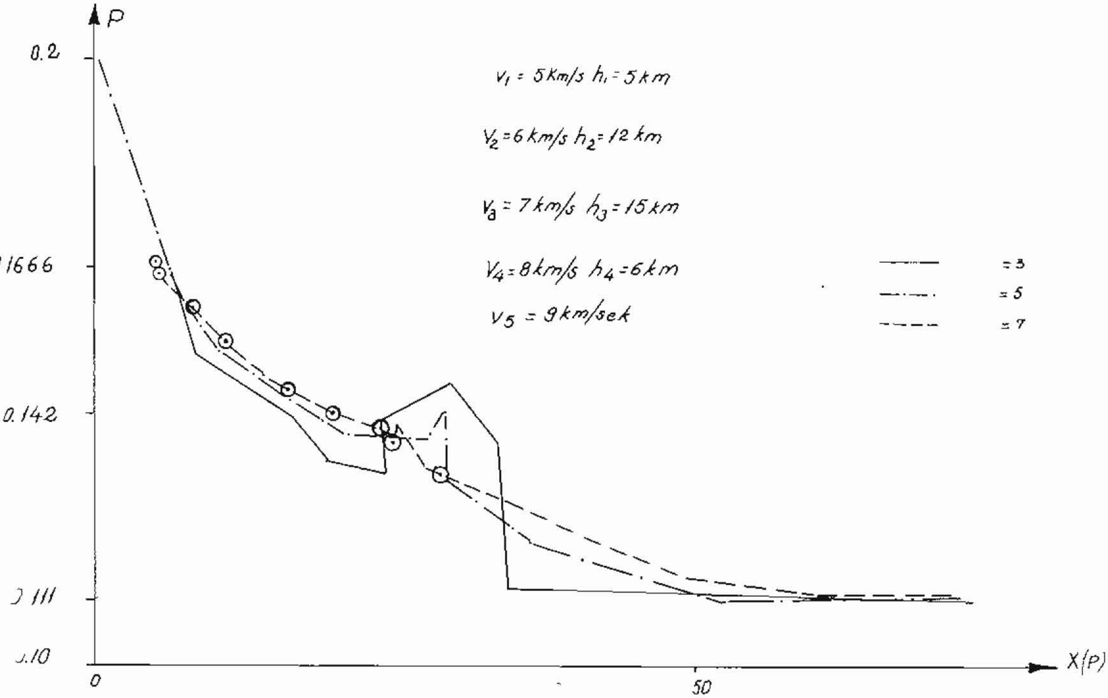

Fig.2. X(p) behaviour for different step intervals.

1.1.3. Data and Outputs

Hodochrones of about 300 earthquakes with M =4.0-5.5 for the period 1977-1983, situated in Albania and surrounding areas were taken into consideration. Data analysis and interpretation was made according to following criteria:

- Velocity values of different layers of Earth crust are different for different earthquakes,
- There is a predominant velocity value of 6.6-7.0 km/s, which according to DSS data (Dragasevic and Andric, 1974; Morelli et al., 1969), can be attributed to the top of granitic layer, situated at 12km depth (at Drini Gulf in Adriatic Sea) up to 15 km (in Dinarides).
- Upper part of consolidated Earth Crust is presented by P wave velocities values 6-6.2 km/s and less by 5.86 km/s ones.
- Surface velocity is Vo=5.5 km/s, except for the Northeastern Albania (Vo=4.6 km/s).

Based on these data the structure of Earth Crust for different parts of Albania is presented in Table 1.
From the Table 1, it can be seen that the thickness of the Earth Crust is greater in eastern Albania (up to 50 km) and smaller towards Adriatic Sea (36 km).
The thickness of sedimentary layer is greater in coastal zone of Albania (3-12 km) and smaller in Eastern Albania (5 km).
The thickness of consolidated crust is greater in Eastern Albania(8-11 km) and smaller in coastal zone (3-3.7 km).

Table 1. Earthcrust structure in Albania according to $\mathcal{F}(p)$ mapping.

Region	Vo km/s	hs km	v1 km/s	h1 km	v2 km/s	h2 km	v3 km/s	h3 km	v4 km/s	h4 km	v5 km/s	h5 km
SWALB	5.5	12	6.2	3.4	7.06	18.6	7.73	2	8.01	2	8.28	42
PAD	5.5	8	6.1	3.7	7.01	12.3	7.70	16	7.98			
SEALB	5.5	5	5.9	11.0	7.12	13.0	7.63	13	7.92			
NEALB	4.6	5	6.1	8.0	6.89	14.0	7.53	20	7.84	5	8.10	
NWALB	5.5	9	6.2	3.0	6.63	15.0	7.71	23	7.93			

Note: PAD- Preadriatic depression , ALB - Albania

Concerning Moho discontinuity, it was accepted that the velocity of Upper Mantle beneath this discontinuity variate from 7.84-8.01 km/s with mean value of 7.96 km/s (Kociaj et al., 1977). In our previous studies (Kociaj et al., 1977; Kociaj et al., 1979) it was shown that the lack of Pb phase can be explained either by small thickness of basaltic layer (9-10 km) or by low velocity layer.

From the Table 1 it can be seen that between the basaltic layer and consolidated crust there is an intermediate layer (12-14 km thick, with velocity 6.6-7.1 km/s), thicker in SW Albania (18.6km). There is an opinion that velocities 6.8-7.2 km/s should be characteristic for basaltic layer(Kociaj,1986). In that case this intermediate layer may represent the basaltic layer, as the transition from the Upper Crust to Mantle is gradual one. From above mentioned it can be seen that the earthcrust structure in coastal zone of Albania (and especially in Ionian coast) is quite different from other parts of Albania, which can be explained by an asthenosphere closer to surface than in other parts.

1.2. The first onsets as refracted -reflected waves.

The first onsets of great amplitudes can be considered as refracted-reflected waves.Using smoothed hodochrones by cubic spline method (Pitarka 1986), were found :

1.2.1. - Maximum depths (zmax) of the penetration of the seismic rays (Giese 1970).

1.2.2. - Minimum depths (zmin) of the penetration of the seismic rays (Gerver and Markushevic 1972).

1.2.3. Direct inversion of hodochrones.

For the direct inversion of hodochrones the method proposed by Burmin(1981), was used, to determine the depth of the penetration of the seismic rays (h_k) in multilayered medium.

1.2.4. For low velocity layers (LVL), based on parametric hodochrones (Burmin 1978), the algorithm proposed by Colombo and Scarascia (1973) was used, to determine the structure of LVL (Kociaj 1985).

1.2.5. Inversion through $\mathcal{F}(p)$ and $\xi(p)$ parameters as the solution of a linear problem.
Is presented as the solution of matrix system (Dorman and Jacobson 1981):

$$A\,x=c \qquad (4)$$

where : c represents the vector of observed data,
x represents unknown vectors $(dz/dv)j$,
A matrix of coefficients relating c to x and expressed through analytical expressions for $\mathcal{F}(p)$ and $\xi(p)$.

1.2.6. Data and Outputs.
The same set of data as was used mentioned in the first paragraph. All the data were inverted according to the above mentioned methods (1.2.1-1.2.5). In the figure 3 is presented the cross section according to the data got from big explosions in Fierza (Northern Albania). As it can be seen an increase of velocities is observed at the depth of about 8-10 km, which can be explained by the presence of ophiolites in this zone. Deeper, a decrease of velocity can be observed for intervals from 10-12km and further we have to deal with velocity behaviour similar to upper part of Earth Crust. This behaviour can be explained by overlapping of ophiolites on normal sediments, characteristic for other zones in Albania. At the depth of about 30 km velocity inversion is observed, which can be influenced by a presence of LVL in Lower Crust.

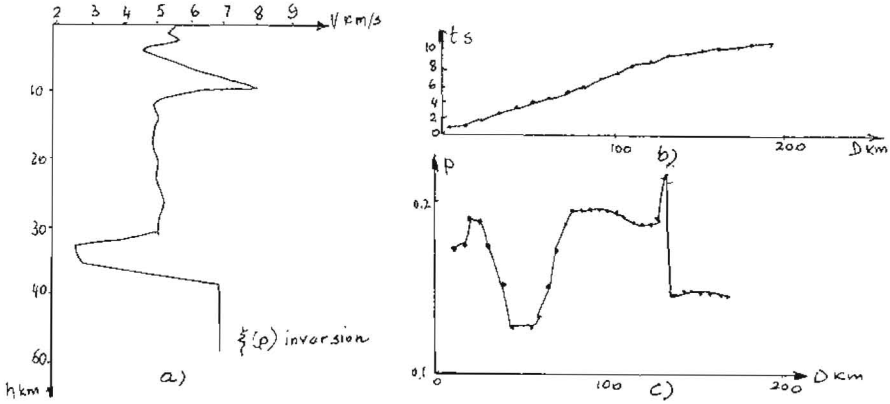

Fig.3. (a) Fierza-Himara cross section according to Fierza's blast recordings. b) Smoothed hodochrones, c) p=f(X) plot.

Some cross sections got from the inversion of earthquake data are presented in figure 4. Comparing them with DSS data it can be seen that inversions using $\mathcal{F}(p)$ and $\xi(p)$ parameters (see item 1.2.5) are fitting better. Four types of the Earth Crust can be distinguished (Fig.4):

First type: normal crust, with positive values of velocity gradients. Similar outputs by both methodologies (1.1,1.2), (Fig.4a).
Second type: velocity inversions within the Earth Crust at different levels (Fig.4b). Velocity gradients are changing at depth intervals 11-16 km , 30-35 km and at about 50 km.
Third type: crust with velocity inversions just beneath it (figs. 4b and 4c), which means that there a LVL can be observed.
Fourth type: crust with double velocity inversions beneath it (figs. 4d), which coincides with conclusions made for Adriatic Sea by other authors (Calcagnile and Scarpa 1985).

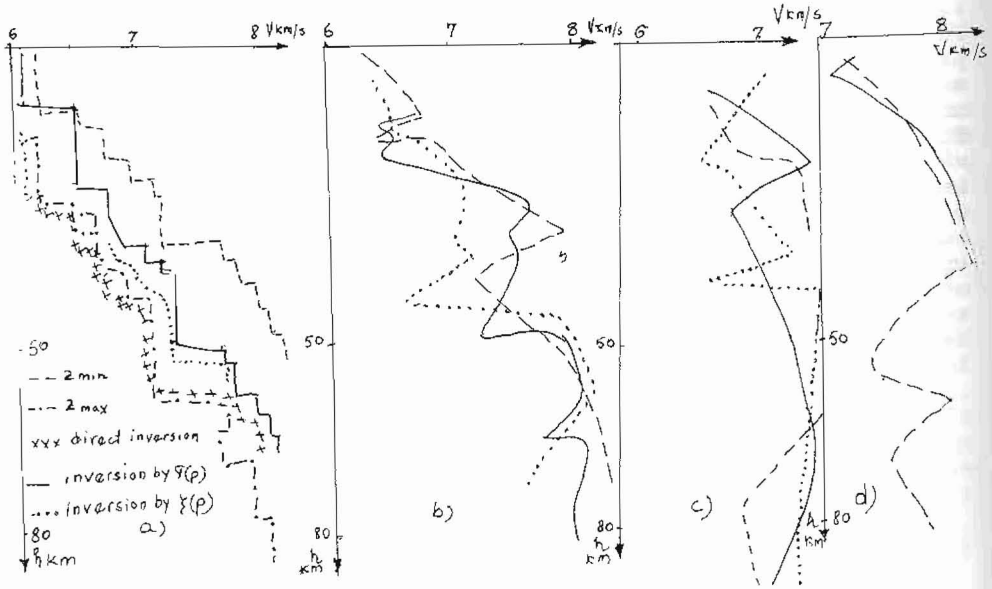

Fig.4. Four types of Earth Crust structure in Albania.

2. CORRELATION OF SEISMOLOGICAL AND GRAVIMETRIC DATA.

Taking into account relative values of Bouguer anomalies observed in Albania (Bushati, 1983), and the thickness of the Earth Crust at epicenters of earthquakes taken into consideration, an attempt was made to find the thickness of Earth Crust according to Bouguer anomalies values. It was observed that the best correlation was reached using values got by ξ(p) inversion data (Kociaj, 1985):

$$H(Km) = -0.19\Delta g - 1.15 \qquad (5)$$

Using the data of neighbouring to Albania countries (Dragasevic and Andric, 1974; Makris, 1973), a schematic map of the thickness of Earth Crust was compiled for Albania (see figure 5). It can be seen that western part of Albania is divided from eastern part by a very deep trench of SE-NW direction, from Gramozi mountains to Rodoni Cape. Two deep transversal faults: Shkoder-Peje, and Vlore-Diber-Skopje (SW-NE direction), with high seismicity, can be distinguished as well.

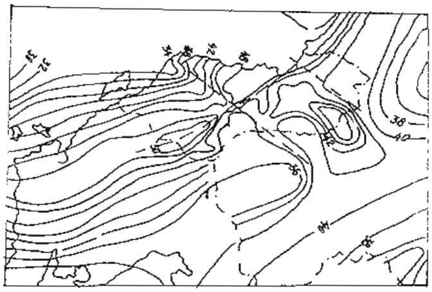

Fig.5. The thickness of Earth Crust in Albania.

CONCLUSIONS

- The Earth Crust in Albania, has a complicated character, from its sharp transition to the Upper Mantle up to the gradual transition with velocity inversion inside the Upper and Lower Crust and beneath it. Its greater thickness reaches 50 km, while that smaller 34 km. There exist in general a thining of Earth Crust towards West, Adriatic Sea and SW Albania.
- Velocity inversion under Earth Crust, especially in SW Albania, shows for aproximity of asthenosphere in this region, which can be linked with the high seismic activity in coastal areas.
- The division of Earth Crust by deep faults(of two main directions) can explain the high seismic activity along them. The Upper Crust is of a blocky character, expressed by velocity contrasts and concentrated seismic acitivity at their edges.

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