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Bruno Colombi, Ignazio Guerra, Giuseppe Luongo, Salvatore Scarascia

Report on seismic measurements along the profile Lawrencepur-Astor (Karakorum Geophysical Project 1975)

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Geofisica. — *Report on seismic measurements along the profile Lawrencepur-Astor (Karakorum Geophysical Project 1975).* Nota di BRUNO COLOMBI (*), IGNAZIO GUERRA (**), GIUSEPPE LUONGO (***) e SALVATORE SCARASCIA (*), presentata (****) dal Socio A. DESIO.

RIASSUNTO. — Si riportano i risultati di un profilo sismico profondo effettuato in territorio pakistano nell'estate 1975 lungo la direttrice Nanga Parbat–Lawrencepur. Questo profilo costituisce il segmento meridionale di un insieme di profili (Lawrencepur–Nanga Parbat–Zorkul–Karakul) esplorati in territorio pakistano e sovietico nell'ambito di un progetto internazionale per lo studio delle strutture crostali nelle regioni orogeniche del Karakorum, Hindukush e Himalaya. Lungo il profilo esplorato si è rilevato uno spessore della Crosta che aumenta in direzione NE da 59 a 65 km e una transizione «morbida» (valori bassi del gradiente di velocità delle onde sismiche) tra strati inferiori della Crosta e strati superiori del Mantello.

1. INTRODUCTION

During August 1975 a large scale seismic refraction profile was explored in Karakorum region, in international cooperation (U.S.S.R., Pakistan and Italy) under the title "Karakorum Geophysical Project". For the exploration of this profile 8 shots were fired in 4 points of which 2 in Pakistan territory (Lawrencepur and Astor) and 2 in USSR territory (Zorkul and Karakul).

This report deals with results obtained along the profile Lawrencepur-Astor, using only shots at the ends of this profile.

On this line observations were carried out by the group of Milan (Istituto per la Geofisica della Litosfera of CNR, Istituto di Geologia and Istituto di Mineralogia of Milan University, Istituto di Geologia of Pavia University), and Naples (Osservatorio Vesuviano and Istituto di Geologia e Geofisica of Naples University) by means of 6 and 8 recording apparatuses respectively. All stations were of the Mars 66 type, with time signal received via radio or generated by quartz clocks: in the last case also another radio signal was recorded on the second channel of the tape, in order to check the clocks. The group Naples had a strip chart recorder too, for monitoring one of the stations.

Data on shot points are reported in Table I. 28 recording points were occuped, distributed over a distance of about 240 km. Their coordinates and elevations are reported in Table II: A and B indicate recordings on 15th

(*) Istituto per la Geofisica della Litosfera - C.N.R. - Milano.

(**) Osservatorio Vesuviano - Ercolano (Napoli); also at Dipartimento di Scienze della Terra - Università della Calabria - Castiglione Scalo (Cosenza).

(***) Osservatorio Vesuviano - Ercolano (Napoli); also at Istituto di Geologia e Geofisica - Università di Napoli.

(****) Nella seduta del 6 dicembre 1980.

TABLE I.

List of shot points and charge sizes.

SHOT NO.	DATE	TIME (GMT)			LOCATION	GEOGRAPHIC COORDINATES		ELEVATION	CHARGE
		h	*m*	*s*		LATITUDE N	LONGITUDE E	(*m*)	(*t*)
1	15 Aug. 1975	00	59	40.36	Karakul	39° 05′ 00″	73° 25′ 00″	4090	5
2	»	01	59	59.50	Zorkul	37° 47′ 00″	74° 10′ 00″	4126	10
3	»	02	59	54.996	Astor	35° 20′ 00″	74° 47′ 42″	3562	1.6
4	»	03	59	58.13	Lawrencepur	33° 50′ 48″	72° 27′ 24″	390	2
1 A	20 Aug. 1975	00	59	40.64	Karakul	39° 05′ 00″	73° 25′ 00″	4090	10
2 A	»	01	59	57.50	Zorkul	37° 47′ 00″	74° 10′ 00″	4126	2.4
3 A	»	02	59	55.395	Astor	35° 20′ 00″	74° 47′ 42″	3562	2
4 A	»	03	59	51.96	Lawrencepur	33° 50′ 48″	72° 27′ 24″	390	2

TABLE II.

Coordinates of the recording points.

STATION NO.	LATITUDE N	LONGITUDE E	ELEVATION (m)
1 A	33° 49′ 37″	72° 37′ 48″	500
1 B	33° 49′ 36″	72° 44′ 14″	500
2 A	33° 54′ 18″	72° 47′ 28″	550
2 B	33° 58′ 56″	72° 54′ 24″	550
3 A	33° 58′ 24″	73° 00′ 07″	650
3 B	34° 00′ 26″	73° 06′ 20″	750
4 A	34° 05′ 46″	73° 10′ 32″	1050
4 B	34° 09′ 50″	73° 12′ 03″	1450
5 A	34° 14′ 30″	73° 14′ 24″	1250
5 B	34° 20′ 24″	73° 15′ 00″	1200
6 A	34° 24′ 03″	73° 19′ 35″	1250
6 B	34° 29′ 53″	73° 21′ 04″	900
7 A	34° 32′ 42″	73° 21′ 13″	1150
7 B	34° 37′ 32″	73° 25′ 51″	1250
8 A	34° 39′ 20″	73° 30′ 50″	1400
8 B	34° 43′ 25″	73° 31′ 29″	1500
9 A	34° 49′ 17″	73° 34′ 48″	2150
9 B	34° 51′ 59″	73° 36′ 28″	2400
10 A	34° 55′ 39″	73° 41′ 26″	2480
10 B	34° 56′ 20″	73° 46′ 34″	2700
11 A	34° 56′ 49″	73° 52′ 32″	2910
11 B	34° 59′ 52″	73° 57′ 01″	3100
12 A	35° 05′ 11″	73° 55′ 46″	3400
12 B	35° 07′ 11″	73° 58′ 50″	3550
13 A	35° 11′ 03″	74° 03′ 44″	3400
13 B	35° 15′ 45″	74° 06′ 23″	2100
14 A	35° 16′ 31″	74° 08′ 02″	1620
14 B	35° 23′ 43″	74° 08′ 22″	1300

TABLE III.

Profile Lawrencepur-Astor (Karakorum Geophysical Project).

List of Italian institutions and people partecipating in field recording operations.

Milan Group

Istituto per la Geofisica della Litosfera - CNR - Milano: P. Cardamone, V. Carli, B. Colombi, S. Scarascia.

Istituto di Geologia - Università di Milano: F. Forcella, G. Orombelli.

Istituto di Mineralogia - Università di Milano: B. Biggiogero, A. Ferrario.

Istituto di Geologia - Università di Pavia: R. Casnedi.

Naples Group

Osservatorio Vesuviano - Ercolano: I. Guerra, A. Lo Bascio, G. Luongo, R. Scarpa.

Istituto di Geologia e Geofisica - Università di Napoli: M. Cortini, V. D'Isanto, P. Gasparini, A. Rapolla, P. Scandone.

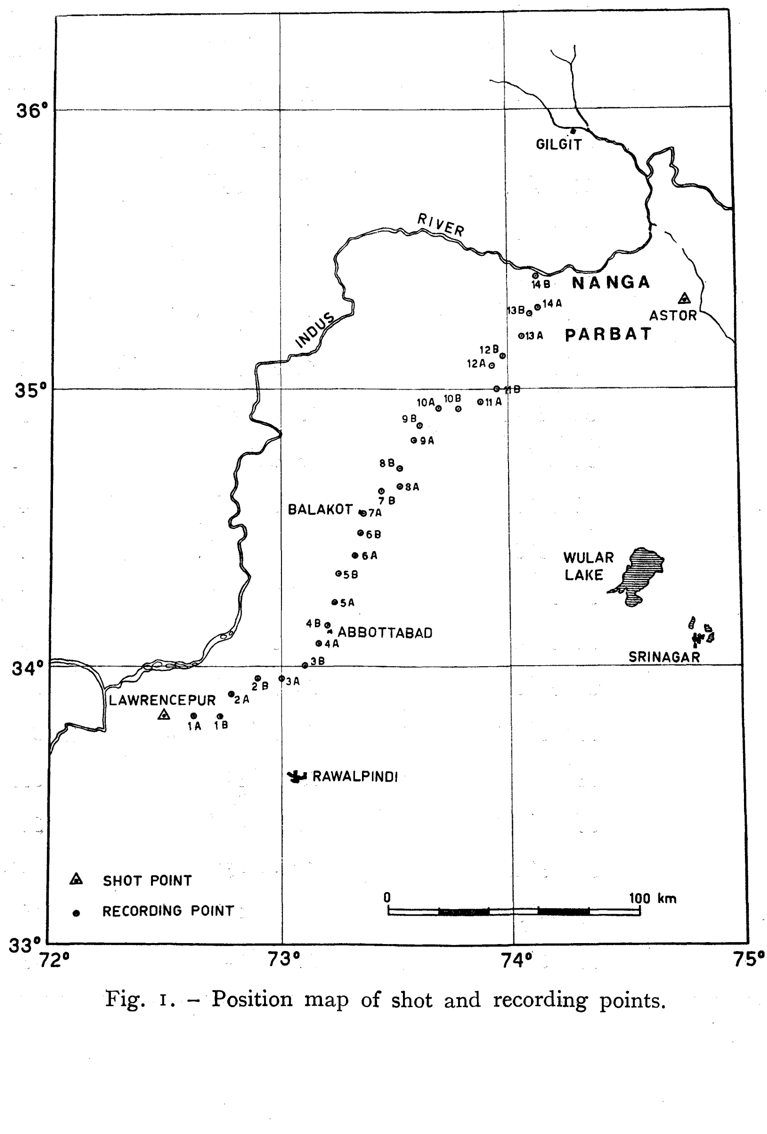

Fig. 1. - Position map of shot and recording points.

and 20th August respectively. Their positions are shown in Fig. 1. Some recordings were not utilizable due to technical failure.

In Table III a list of Italian Institutions and people partecipating in the field recording operations is given.

2. RECORD SECTIONS AND MAIN WAVE GROUPS

Two record sections referred to Lawrencepur and Sango Sar Lake shots were compiled. They are made up by 20 and 21 records respectively and are shown in Fig. 2 and 3.

The following wave groups appear in the record sections:

a) Record section referred to Lawrencepur shot point:

1) P_g wave group (line 0–1) up to a distance of 125 km; the velocity of 6 km/sec is reached at a distance of about 50 km from the shot point;

2) a reverse branch (3–2) between 165 and 230 km;

3) P_n waves appearing at a distance of 210 km.

In the distance range between 100 and 180 km the received energy is very low. Therefore the onsets of the wave groups are very weak and correlation cannot be well recognized. Due to the same reason one cannot exclude the presence of an intermediate correlation line between the 0–1 and 3–2 branches. At present no final interpretation concerning the time delay between these two lines can be given: this delay may be interpreted as due either to a single thick low-velocity layer or to some low-high velocity layers alternations. However these considerations do not modify at a significant degree the results about the structures underlying the low velocity layers (Colombi and Scarascia, 1973).

b) Record section referred to Astor (Sango Sar Lake) shot point:

1) P_g wave group (line 0–1) up to a distance of 110 km; the velocity of 6 km/sec is reached at the distance of about 60 km from the shot point;

2) a reverse branch 3–2 in the distance range 110–140 km;

3) a reverse branch 5–4 in the distance range 125–150 km;

4) a reverse branch 7–6 in the distance range 170–240 km;

5) P_n waves group appearing at more than 200 km from the shot point.

The inverse branches 3–2 and 5–4 are quite reliable, due to the strong outsets of the wave groups. This fact shows a good transmission of the seismic energy, in contrast to the results obtained for the other record section.

On the contrary the same problem as in the previous case arise concerning the time delay between branches 5–4 and 7–6.

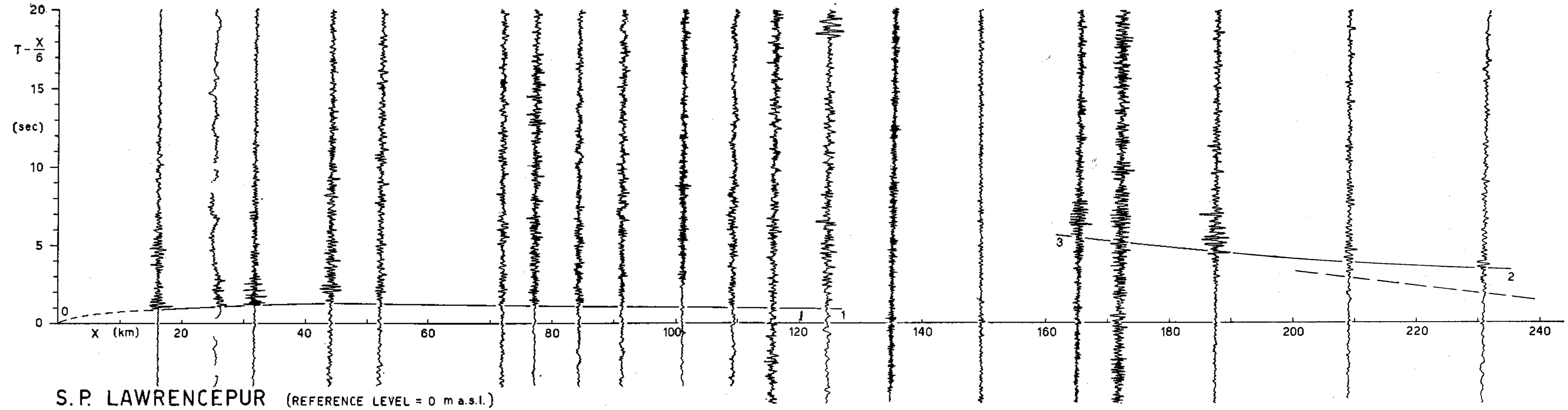

Fig. 2. – Record-section from Lawrencepur towards Astor.

N.B. da ridurre a 22 cm di base

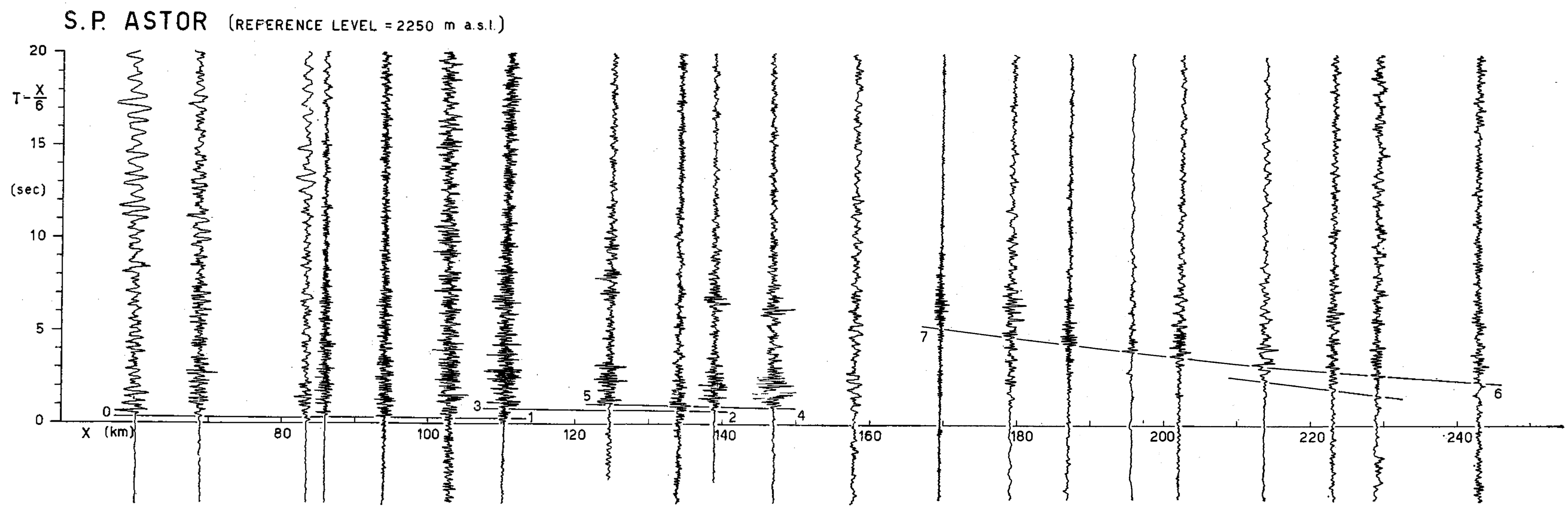

Fig. 3. – Record-section from Astor towards Lawrencepur.

3. VELOCITY–DEPTH FUNCTIONS AND CRUSTAL STRUCTURE

In order to infer the geological structure from seismic data, it is necessary to evaluate the velocity-depth function from the record sections. The conversion of time-distance data into velocity-depth functions was obtained assuming a crustal model characterized by thin horizontal layers in which velocity values change linearly with depth. The velocity-depth function was evaluated by computer, starting from the uppermost layer and going down to the lower ones (details of this elaboration method are given in Colombi and Scarascia, 1973, or in Morelli *et al.*, 1975).

Fig. 4 and 5 show the plots of the results given by the computer. Of course they reflect the main features already shown in the record sections. In fact it is possible to see, with reference to the Lawrencepur shot point, only one low velocity layer in the depth range 12–42 km.

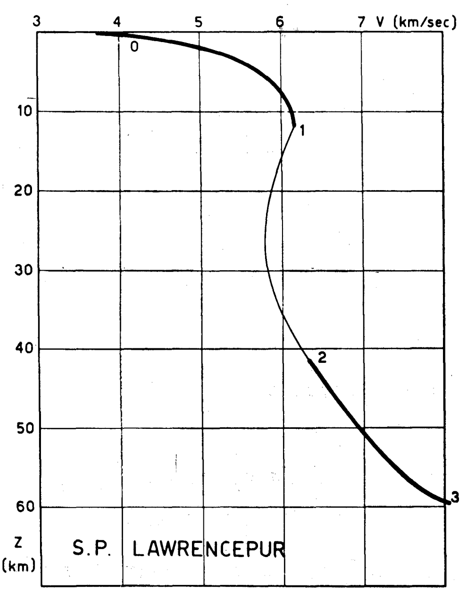

Fig. 4. – Velocity-depth function from the shot point Lawrencepur.

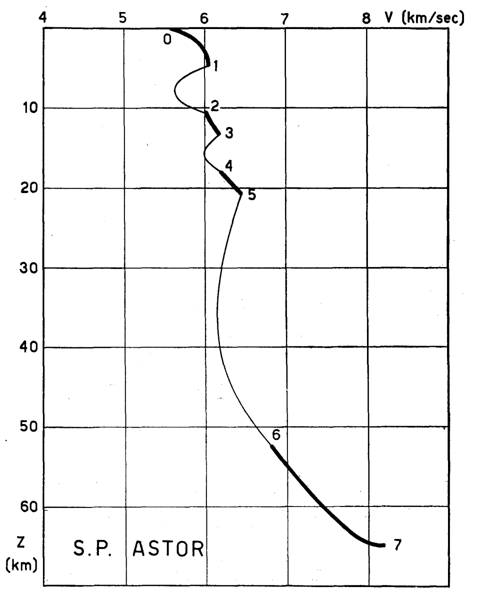

Fig. 5. – Velocity-depth function from the shot point Astor.

The low velocity value in the surface layers corresponds to the presence of a thick sedimentary cover in the Indo-Gangetic foredeep.

The 8 km/sec velocity value is reached at the depth of 59 km. In the lowermost crust the velocity gradients is quite low, indicating a smooth transition from crust to mantle.

The velocity-depth function referred to the Sango Sar Lake shot point is more detailed, because of the larger number of correlation lines in the record section.

In this case a thick low velocity layer is obtained between 21 and 52 km and two thinner ones in the upper crust.

The surface velocity value is very high (5.6 km/sec): from a geological point of view this value has to be attributed to metamorphic layers of the intermediate crust.

The 8 km/sec velocity value is reached at the depth of 65 km. Also in this case the velocity gradient in the lowermost crust indicates a smooth transition from crust to mantle.

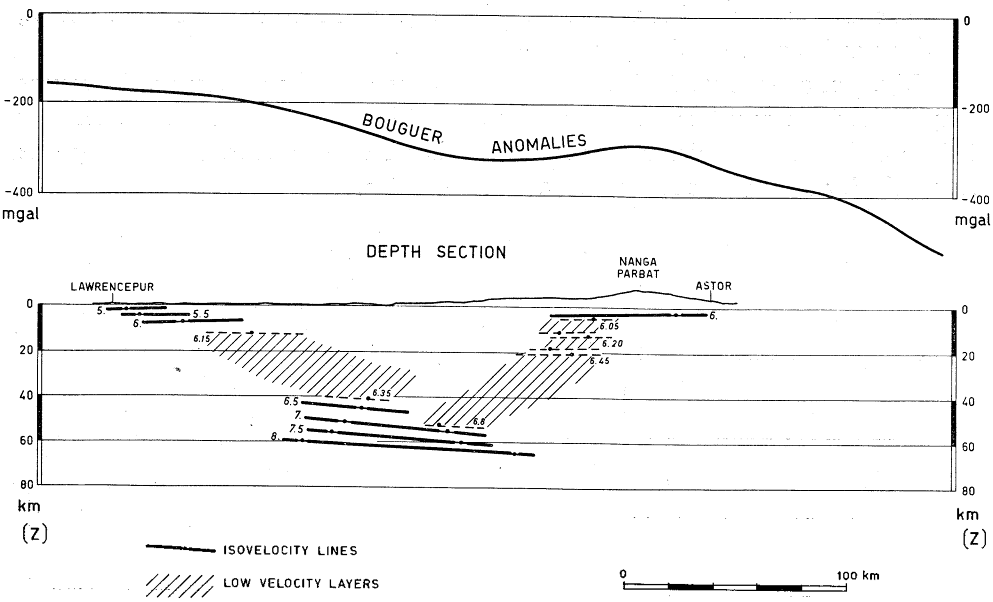

Fig. 6. – Crustal section Lawrencepur-Astor.

The available data allow us to outline the trend of the isovelocity lines as shown in Fig. 6. The main features of this crustal section are:

a) an increasing thickness of the crust from Lawrencepur towards Astor (from 59 to 65 km, in a distance range of about 100 km).

b) a thick low velocity layer everywhere along the profile; however the velocity inversion is moderate, its average value not exceeding 5 %.

c) high velocity surface layers near the northern end of the profile (Nanga Parbat complex);

d) thin low velocity layers in the uppermost crust in the same region.

The crustal thickness deduced by seismic data is coherent with the Bouguer anomaly as shown in the same Fig. 6. The anomaly is in fact negative and increasing when going northwards. A relative positive anomaly is observed in the Nanga Parbat region, where high surface velocities are found.

4. GEODYNAMICAL IMPLICATIONS

The seismic refraction profile does not cross a complete orogenic system. Therefore any possible inference has to be considered as a working hypothesis.

The profile crosses a part of the Himalayan mountain chain, which is one of the most remarkable tectonic features generated by the collision between drifting plates. Seismic and geological data (distribution of earthquake foci, focal mechanism solution and structural trends) indicate that in this area the collision is due to the relative motion of the Indian plate towards the Euro-Asian block. This is one of the most consolidate statements of the plate tectonics: however disagreement still exists among geophysicists about the consequences of the collision.

Some authors (e.g. Molnar *et al.*, 1973) suggest that Central Asia is a tectonically passive unit and ascribe the infra-continental seismicity solely to the convergence of the Indian plate with Asia. On the contrary other authors (e.g. Das and Filson, 1975) propose a more detailed model: the seismicity of Central Asia could be due to interaction of several smaller blocks which move in response to internal as well as external stress sources.

These different interpretations show that the area is highly complicated. At present the collision is between two continental masses: the remnants of the ocean which divided these continents are visible in the Indus suture zone and evidence of an under-thrusting slab is given by intermediate earthquakes in Hindu Kush. For the Lower Himalayas, Oxbourgh (1972) puts forward the hypothesis of the formation of a crustal flake after continental collision. According to this concept, large masses from upper crust of one continental plate should be torn up to be driven over the second one for very large distances.

In conclusion, following this idea it is possible to justify the main features of the crustal section obtained by seismic data. In fact the large crustal thickness and the high velocity values of surface layers are compatible with the collision between two continental masses, which provokes the splitting of lower and upper crust of one of them. Between these parts the crust of the second block intrudes. Such a layering may be the determining factor for the presence of low velocity layers, which in this area are difficult to justify by the same argumentations as in other regions tectonically more stable.

Acknowledgements. — The financial support for the Italian partecipation to the Karakorum Geophysical Project was furnished by Italian National Research Council (C.N.R.).

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