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Intermediate Aseismicity of the Andean Subduction Zone and Recent Andesitic Volcanism

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Abstract. Preliminary investigation of the morphology of the Benioff zone in the Andean South America, based on the distribution of earthquake foci, revealed intermediate aseismic gap in the descending oceanic plate. A close correlation of the occurrence of this intermediate aseismic gap and recent andesitic volcanism in the Cordillera de los Andes was found. This phenomenon may support the hypothesis that the source of andesitic volcanism is the partially melted zone of the oceanic lithospheric plate.

Key words: Seismicity – Andesitic volcanism – Plate tectonics – Andean South America.

The recent volcanism and seismic activity in the Pacific region are generally interpreted as a consequence of the acting global plate tectonics. It seems that andesitic volcanism is spatially bound to the areas characterized by the existence of seismically active Benioff zones. This was confirmed mainly for the island arcs of the western Pacific region (Kuno, 1966; Dickinson, 1968; Hatherton and Dickinson, 1969). No equivalent attention has been paid to the Andean region, although several papers on its seismicity were published (Santô, 1969; James, 1971; Stauder, 1973; Teisseyre et al., 1974).

The accuracy of the earthquake foci determination in the South American region substantially increased after 1966 (Santô, 1969). The ISC data (Regional Catalogue of Earthquakes) for the four years' period 1967–1970, completed by the data of deep shocks from the catalogue of Rothé (1969) for 1953–1965, were used in the present study. The relatively high seismicity of the Andean South America and nearly meridional course of the Peru-Chile trench allowed us to divide the active seismic belt between 0–35° S into 35 parallel sections with a width of 1° of latitude, for which graphs giving the depth distribution of earthquake foci in dependence on longitude were constructed (as an example, two of these sections are given in Fig. 1). According to minor seismicity south

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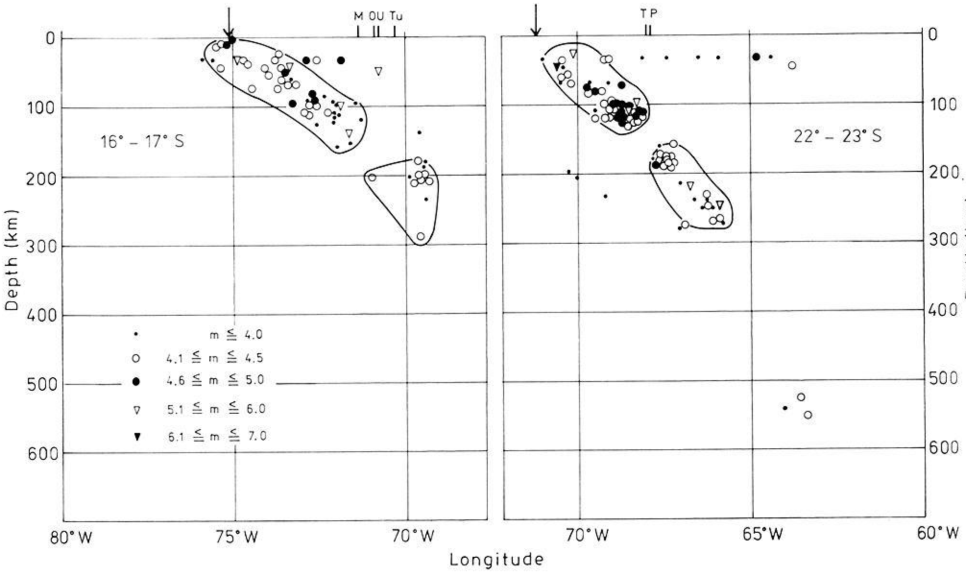

Fig. 1. Two parallel vertical sections of the Benioff zone under the Andes between 16°–17° S and 22°–23° S giving the distribution of earthquake foci in dependence on longitude; m-ISC magnitude; volcanoes are denoted by short vertical lines (*M* Misti, *O* Omate, *U* Ubinas, *Tu* Tutupaca, *T* Tatio, *P* Putana), position of the Peru-Chile trench by arrows

of 35° S only three sections were constructed for the southern part of the Andes. Thus a detailed picture of the morphology of the Benioff zone, characterizing the collision of the Nazca and South American plates, could be obtained for the area limited by 0°–45° S and 60°–85° W.

On the basis of the above 38 parallel sections the seismic activity of the Benioff zone could be divided into three zones of shallow, intermediate and deep seismicity[1], separated by a distinct aseismic gap in the laterally variable depths of about 100–200 km, and by an aseismic region between 300 and 500 km. A generalized meridional section of the activity of the Benioff zone (Fig. 2) was constructed so that the shocks with minimum and maximum focal depth in all three zones were taken as their limits at the corresponding interval of latitude. Whereas the zone of shallow seismicity seems to be continuous along the whole section, the zones of intermediate and deep seismicity are interrupted in several places. No foci of intermediate depth have been located between 7° S and 14° S, as well as between 25° S and 27° S, 29° S and 31° S, and south of 40° S. A similar picture was obtained in the recent study by Teisseyre et al. (1974), as well as in papers of Santô (1969) and Stauder (1973), in the last two papers the intermediate aseismic gap appearing as a zone of decreased seismicity. The clear occurrence of this gap in our work is probably caused by more detailed treatment of data and by usage of the revised data after 1966.

[1] Here the meaning of shallow and intermediate seismicity is different from the formal definition of Gutenberg and Richter (1954)

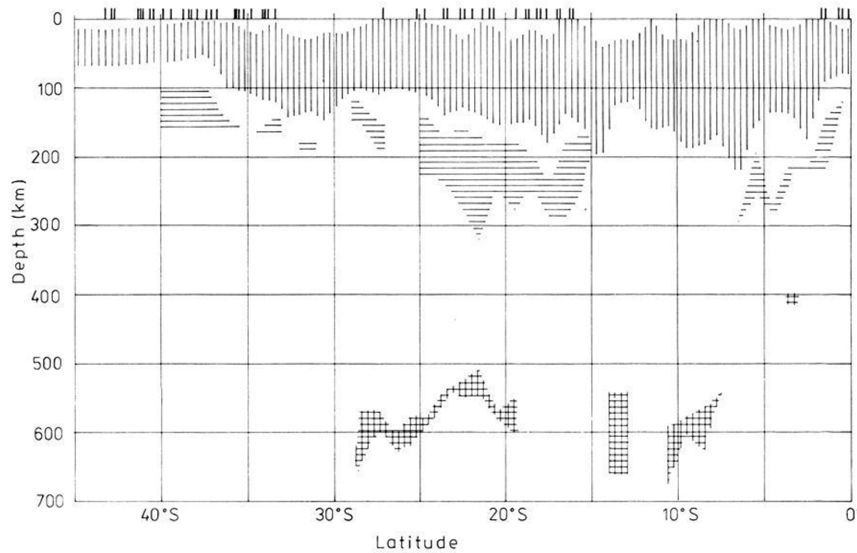

Fig. 2. Meridional section of the Andean seismicity between 0° and 45° S. Zones of shallow, intermediate and deep seismicity are denoted by vertical, horizontal and cross hatching, respectively, volcanoes by short vertical lines

If we correlate the meridional section of seismicity with recently active Andean volcanoes (Gutenberg and Richter, 1954; Gonzales-Ferran, 1972), the positions of which are indicated by short vertical lines in the upper part of Figure 2, a striking spatial relation appears between the occurrence of the intermediate aseismic gap and recent andesitic volcanism in the Cordillera de los Andes. In order to show clearly the above relationship, the surface projection of the intermediate aseismic gap, laterally extending from the westernmost shock with maximum depth of the shallow zone and the easternmost shock with minimum depth of the intermediate zone in parallel sections, and the areal distribution of Andean volcanoes are drawn in Figure 3. The numbers along the contours of the aseismic gap give the depth of the lower boundary of shallow seismicity and that of the upper boundary of intermediate seismicity, respectively.

The picture in Figure 3 confirms the close correlation between the occurrence of the intermediate aseismic gap and the position of active volcanoes. The vertical section of the gap is characterized by a nearly constant thickness of about 40 km between the shallow and intermediate seismicity (Fig. 2). No intermediate aseismic gap of such a shape can be observed between 3° S and 15° S, where also the Benioff zone is poorly defined and the distribution of seismicity is complicated, the earthquake foci being concentrated in two separated branches. The gap and the volcanic line are further interrupted between 25° S and 27° S, as well as between 29° S and 33° S. The intermediate seismicity disappears south of 40° S showing that the Benioff zone is thinning out at the southern margin of the Nazca plate.

The intermediate aseismic gap separating the shallow and intermediate seis-

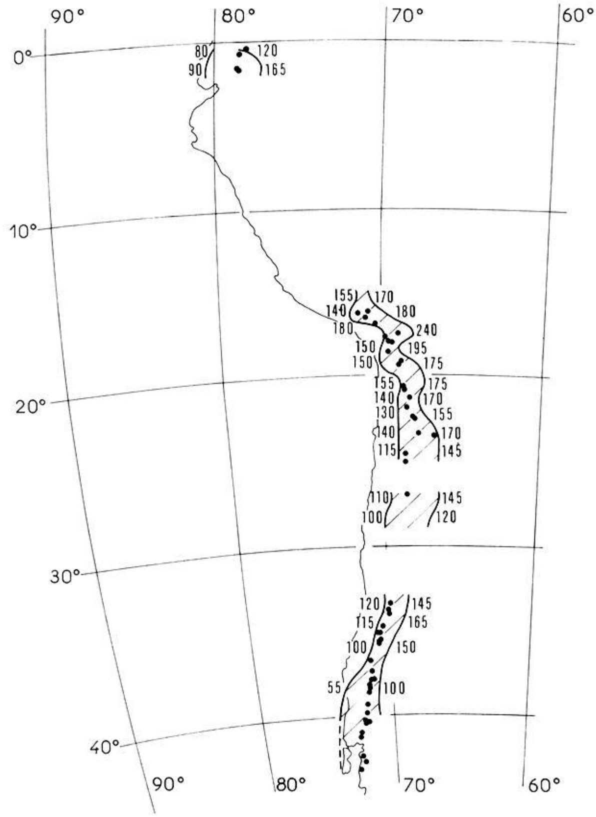

Fig. 3. Surface projection of the intermediate aseismic gap (hatched area) and distribution of active volcanoes (full circles) in the Andean South America. Numbers along contours of the aseismic gap give depth in kilometers

micity of the Andean region, which is spatially related to the occurrence of the recent andesitic volcanoes, indicates possible partial melting of the supposed descending oceanic plate. The partial melting, probably of the whole thickness of the slab (Fig. 1), can be considered as a source of andesitic magma for active volcanoes (Marsh and Carmichael, 1974). At the same time, the decreased viscosity due to the partial melting of the lithospheric material would exclude the accumulation of stress causing the seismic activity. If the above model is correct, the depth of the magma generation of the Andean andesitic volcanism should roughly be in the range between 100 and 200 km (Fig. 3), which is not in contradiction with data estimated in other Pacific regions (Sugimura, 1966a; Dickinson, 1968; Hatherton and Dickinson, 1969). A tendency of seismic activity to decrease in the depths, assumed to be responsible for the occurrence of primary magma, has been already reported for the Japanese island arc (Sugimura, 1966b). An intermediate aseismic gap seems to occur in the Tonga-Kermadec region (Isacks et al., 1968), and, according to our preliminary investigations, in the Benioff zone of Central America. The possible existence of the partially melted zone in the slab would also modify the model of the Q_P-structure for South America (Sacks and Okada, 1974).

We suppose, similarly as Fyfe and McBirney (1975), that the liberation of water and other volatiles might play an important role in the materialization of most endogeneous processes in the areas of colliding plate margins. Whereas the continuous dehydration in shallower parts of the descending slab may facilitate the plutonic and metallogenic processes in the continental plate, the presence of water in suitable state conditions can cause partial melting in the deeper parts of the slab. Contrary to the latter authors, we assume that the source of andesitic volcanism is the partially melted zone of the oceanic lithospheric plate itself. An open question remains the recent Andean volcanism south of 40° S, which occurs in the region lacking clearly defined Benioff zone and intermediate seismicity. The explanation could be found in the change of the type of volcanism in the southern segment of the Andes (Casertano, 1963).

Similar studies for the region of Central America and for the whole region of the Andean South America on the basis of further seismological data are presently being made.

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