COASTAL NEOTECTONICS IN PERU: SUBDUCTION REGIME AND QUATERNARY VERTICAL MOTIONS

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RESUMEN: Los desplazamientos verticales que ocurren a lo largo de la costa peruana durante el Cuaternario muestran un patrón complejo en que interactúan la superestructura (subducción bajo la margen andina), las megaestructuras (dorsales asísmicas, estructura cortical del antearco), y las estructuras tectónicas locales. Se analiza la posible influencia de distintos factores geodinámicos en esta zona de subducción sobre la tectonica costera.

KEY WORDS: Neotectonics, vertical movements, subduction, Peru

INTRODUCTION

Neotectonic studies in coastal regions can include precise information on relative and absolute vertical deformation in the course of the last 1-2 my. Marine terraces and Pleistocene shorelines which indicate the former position of a referential horizontal plane (the geoid), at given instants of the past, provide useful data for the reconstruction of both local and regional vertical motions.

For a long time, the Peruvian coast has been recognized as an emergent area (Bosworth, 1922; Steinman, 1929; Broggi, 1946). Recent extensive work on the Peruvian marine terraces now provides a good overview of their distribution along the 3,000 km long coastal zone and also local detailed studies that include geochronological determinations. This work aims to analyze the Quaternary vertical motions, as deduced from marine terrace data, in the area 4°-19°S, and to investigate relationships that link the local/regional deformation pattern and several parameters of the subduction regime.

TECTONIC SETTING OF THE PRESENT-DAY SUBDUCTION IN PERU.

Subduction of the Nazca Plate beneath the South American Plate.

The contact between the Nazca and South American plates is figured on the ocean floor by the Peru-Chile Trench. The trench is grossly parallel to the Peruvian coast, although the shortest distance between these two features varies from 215 km (Trujillo, 9°S) to 65 km (Cabo Blanco-Talara, 5°S). For the last 10 my, at the latitude of Peru, the mean convergence strike and rate have remained stable around the respective values of N080°E and 10 cm/y (Pardo & Molnar, 1987).

The seismicity in Peru, which helps to document the subduction regime, include three groups of events: a) "interplate" events, directly associated to the subduction process and to the east-dipping Wadati-Benioff zone down to a 300 km depth; b) "intraplate" shallow events (<30 km), related to active faulting of the Andean system; and c) deeply-seated events (down to 700 km) which remain poorly understood. The earthquakes of the first group are by far those which release the greatest amounts of energy and elastic deformation.

Geology and structure of the Peruvian coast

The Peruvian coastal region lies upon the Andean forearc, between the trench and the Western Cordillera. During the Tertiary, several sedimentary basins developed on a basement formed by Precambrian and Paleozoic metamorphic rocks and Mesozoic volcano sedimentary arc terranes (Macharé, 1987). The late Tertiary tectonic activity was characterized by tensional stress with basin subsidence interrupted by short-lived compressive pulses that produced uplift of the basins. In Quaternary times, the continental shelf and the emerged coastal region experienced relatively complex and strong deformation: subsidence in the shelf area and vertical uplift motions along the coast that locally reached amplitudes of several hundred meters (up to 1 km, in either direction). The magmatic arc, located on the Western Cordillera, has been active, during the Quaternary, only south of latitude 15°S.

THE THREE SECTORS OF THE PERUVIAN COAST

The main characteristics of the Pleistocene marine terraces (elevation, chronology, deformations) and their distribution along the Peruvian coast were described in a series of papers and doctoral thesis (Sébrier, 1978; DeVries, 1984, 1986, 1989; Macharé, 1987; Hsu, 1988; Hsu et al., 1989; Ortlieb & Macharé, 1990a; Goy et al., 1992). Synthetic analyses of regional deformation deduced from marine terrace data were recently performed in the southern sector of the Peruvian coast (Ortlieb & Macharé, 1990b; Macharé & Ortlieb, 1991, 1992; Hsu, 1992).

The northern Peruvian coast, between 4° and 6°S, shows evidence of uplift motions with mean rates of the order of 150-200 mm/10^3y. Local tectonic factors, including block tilting, upwarping and faulting activity, account for some variations of this mean regional uplift rate and for the geometric deformation of the northern coast "tablazos". Late Quaternary (=last 125 ky) tectonic activity, characterized by differential uplift of the Illescas faulted block and the northernmost Peruvian coastal region, is evidenced by the attitude of the well-preserved Lobitos tablazo. The steeply dipping faults which deformed the tablazos (with either dip-slip or strike-slip motion) seem to be inherited from Tertiary structures.

The 950-km long central sector of the Peruvian coast (6°-14°S) does not show remnants of Quaternary marine terraces. This particularity may be due either to subsident motions or to a relative stability of the coastal region (lack of net uplift motions)(Sébrier & Macharé, 1980; Ortlieb & Macharé, 1990). Quaternary tectonic structures in the central sector consist in normal faults that strike perpendicularly or obliquely to the coastline and which produced only small net displacements.

As mentioned above, the southern Peruvian coast (14°-18°30'S) received much attention in the last few years. It was shown that most of the area has been uplifted at a rather homogeneous rate (80-180 mm/10^3y) during Quaternary times. However, marine terrace data indicate that the area between Lomitas (14.6°) and Lomas (15.3°S) experienced mean uplift rates ranging from 300 to 430 mm/10^3y; during the Late Quaternary, this area was uplifted at a higher rate (400-500 mm/10^3y), whith a maximum rate observed in the surroundings of San Juan Marcona (700 mm/10^3y)(Ortlieb & Macharé, 1990a). The rapid Quaternary uplift motions registered at San Juan Marcona, which are the strongest reported in South-America, were used in distinct attempts of modeling the influence of the Nazca Ridge subduction (Moretti, 1987; Macharé, 1987; Hsu, 1988, 1992; Macharé & Ortlieb, 1992).

SUBDUCTION RELATED PARAMETERS AND VERTICAL DEFORMATION

As observed on most active continental margins, the subduction regime seems to induce regional crustal uplift of the coastal areas lying above the interplate contact. Examples were provided in peri-Pacific regions (Ota, 1986), the Aegean area (Mercier et al., 1979), Indonesia (Pirazzoli, 1991), etc.. However, this empirical relationship has never been plainly explained. It is possible that the heat accompagnying the subduction process plays a role (thermal dilatation), and/or that isostatic mechanisms are involved.

At a regional scale, the uprising sectors of the Peruvian coast may thus be viewed as showing a "normal" tectonic behaviour in the context of subduction below a continental margin, while the subsident (or "stable") sector of central Peru would appear as "anomalous".

Jarrard (1986) tested possible relationships between a series of subduction parameters, among 39 case areas, by using multivariate analysis. Unfortunately he did not include any parameter "uplift rate of the overriding plate", probably because of the paucity of reliable data in most areas.

The close relationship between the subduction of the Nazca Ridge and the strong uplift motions of the Lomitas-Lomas sector was already addressed (if not fully understood). The fact that the highest uplift rates recorded in the north Peruvian coast (Cabo Blanco) are located at the latitude of the Sarmiento Ridge is probably significant. The N055°E trending, and 1600-m high relief of this ridge that is subducting beneath the Cabo Blanco-Paita area is thought to produce a deformation pattern similar to the one described in the area affected by the subduction of the Nazca Ridge.

The distance from the trench axis to the coastline is definitely shorter for the sectors that experienced high uplift rates than for the central coast of Peru. This distance is in the range 65-115 km in northern Peru, 80-180 km in southern Peru, and 135-215 km in the central coast sector. Thus there may be some link between the two parameters, even if the relationship is apparently not direct and proportional.

A coincidence is noted between the loci of the Quaternary marine terraces and the main outcrops of the Cordillera de la Costa basement. This major unit is an Andean-trending forearc structure preserved on the southern and northern coastal sectors, and which is sunk offshore central

Peru, to form the Outer Shelf High. Quaternary vertical motions thus appear in some way related to older deformation patterns.

Finally, at a smaller scale, differences in uplift motions within uprised coastal sectors are probably related to local/regional structures that follow a general N-S trending effective horizontal stress (Mercier et al., 1992).

In conclusion, our analysis suggests that in Peru the type and rate of coastal vertical motions are rather independent from the rate and strike of the convergence, the obliquity of the convergence relative to the coastline, the slab age and the slab dip. On the contrary, some relationship is envisioned with the presence of Precambrian/Paleozoic basement (Cordillera de la Costa), the distance between the trench and the present coastline, the crustal structure and the density distribution in the upper crust. The relationship between vertical Quaternary movements and the seismic activity (magnitude and frequency of the events) still remains poorly understood.

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