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VIII: Sea level and coastal stability

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In the literature concerning the Peruvian coast, it is commonly stated that this region has been uplifted in the recent past, and that this motion mainly consists in coseismic uplifts. The occurrence of repeated disastrous seisms in the coastal area during the last few centuries and the subduction of the Nazca Plate beneath South America constitute the main arguments of the authors who advocate for recent positive vertical motions of the coast. Yet, up to now, studies documenting such vertical motions have been very limited. It is one of the objectives of a new Franco-Peruvian scientific program (ORSTOM-IGP) to decipher the geodynamic behaviour of the Peruvian coast in Quaternary times, including the Holocene.

Distribution of Quaternary marine terraces in Peru

Pleistocene uplift motions along the coast are evidenced by series of marine terraces in two regions only: northern Peru (north of 7°S) and the southern third of the coastline (south of 14°S).

In the northern region, three main Pleistocene terraces (locally called "tablazos") are classically recognized (Bosworth, 1922). The elevation of the older tablazo, of Early Pleistocene or upper Pliocene age, varies between several tens of meters and +300 m. The lowest marine terrace ("tablazo Lobitos") which may be correlated with the early Last Interglacial (Isostopic Substage 5e) commonly reaches a +20 (±10) m elevation (above present MSL) (Bosworth, 1922; DeVries, 1986). Consequently, it is inferred that in the Quaternary, and more specifically in the last 125,000 y, regional uplift rates have been in the order of 100 mm/1000 y. Holocene emerged coastal sediments are locally present in the northern Peruvian coast: they consist in low-lying salt flats, paleoembayments deposits and beach ridges indicating that coeval sea level has stayed at about +2 or +3 m above present MSL.

In southern Peru, the Pleistocene marine terraces may be more numerous and are often found in staircase disposition, thus suggesting rather continuous uplift motions during the Quaternary. The most rapidly uplifted area is located at San Juan Marcona (15°20'S), where the Nazca Ridge has been subducted under the continent (Macharé, 1987; Hsu, 1988). Except in the San Juan Marcona area where it can reach a +100 m (?) elevation* (Macharé et al., in prep.). Thus, the Quaternary vertical motions seem to be of the same order of magnitude as in northernmost Peru (except for the San Juan Marcona area). In the south, evidences of a Holocene high sea stand are also found in numerous localities at a few meters elevation.

In the central coast (7° to 14°S), no marine Pleistocene terraces have been described. This may be interpreted as an indication of a lack of positive vertical motion, if not of subsidence, during the last 1 or 2 My (Macharé, 1987). But this part of the Peruvian coast, like the two other regions, shows emerged Holocene shorelines. These remnants of a higher Holocene sea stand are precisely the evidences, cited by most of the authors, that the coast is being uplifted.

Holocene tectonic motions vs sea level variations

Archeologists have been struck by the fact that, in several localities, series of prehistoric sites and shell middens are located on paleo-seacliffs at a few km from the present coastline. They interpreted that the recent marine regression thus evidenced, which occurred at 6000-4000 B.P., resulted from one (or several) uplift motion(s) of the land (Craig & Psuty, 1971; Moseley, 1975; Pozorski & Pozorski, 1979; Moseley et al., 1981; Engel, 1983; Sandweiss et al., 1981, 1983; Alva, 1986). What appears to have been a sudden abandonment of the occupation sites, and the fact that the paleoembayments often show well-preserved *in situ* molluscan fauna, led some of these authors to reject the hypothesis that the sea level itself has been lowered. It should have been a sudden and rapid vertical motion. Only a few authors did consider that the emergent coastal features may correspond to a recent sea level change, after a high stand around 6000 B.P. (Bonavia, 1982; Chauchat, 1987).

Besides, some investigators have interpreted

* the I.S. 5e shoreline often lies in southern

that intermittent uplift motions of the coastal region were also evidenced by the formation of a few sequences of Holocene beach ridges, in north-central and northern Peru (Woodman & Polia, 1974; Richardson, 1983). After more precise studies on these beach ridges, involving topographic surveys, the neotectonic origin of these feauturs is abandoned, and a close relationship with the El Niño phenomenon is generally preferred (Sandweiss, 1986; Wells, 1988; Ortlieb et al., 1989).

A need for sea level curves

The Holocene sea level fluctuations along the coast of Peru need to be studied thoroughly. The first postglacial sea level curve, proposed for the Peruvian coast, was elaborated only last year in the region of Santa (9°S) (Wells, 1988). According to this pioneer work, which is based upon a very small number of radiocarbon dates, sea level reached a +1 m elevation at 7000 B.P., and would have stayed below the present datum since about 6000 B.P. Wells (1988) postulates that the sea level began to fall after 6000 B.P. until 3500 B.P., and then rose up to the present. She left open the discussion whether this recent, slight relative rise is due to tectonic subsidence, eustasy, or hydroisostasy.

Of corse, sea level curves for other parts of the coast should be prepared. Now, we have begun to survey the best evidences of Holocene high sea stand along the whole coastline and intend to obtain radiocarbon dates from the significant sites. This study is somewhat complicated by the abundant alluvial deposits infilling the lower valleys and the coastal sand dunes which often hide the remnants of Holocene emerged shorelines. Among the difficulties of the task, let us also mention the effects of two quite distinct phenomena which occur on the Peruvian coast and which are able to modify the sea level significantly: the El Niño and the tsunamis. These two kinds of geodynamic events may leave visible remnants, which, of course, should be distinguished from those produced by longer term sea level fluctuations and vertical land motions.

The Peruvian coast thus presents an array of geodynamical problems which only recently have been adressed. The on-going investigations of the Franco-Peruvian team on this matter (and on the geological record of "paleo-El Niños") are realized in relation to the IGCP Projects 274 and 252, the "Global Change" Program, and several INQUA Commissions and working groups.

At present, we conclude that the Peruvian coastal region may not have been experiencing numerous and/or significant uplift motions in the Holocene. The reconstructed Quaternary vertical movements suggest that a large coastal segment (7°-14°S) was isostatically stable or subsident. Furthermore, it is stressed that in the northern and southern regions, which have been uplifted during the Pleistocene, there are no evidences of stronger relative vertical motions than in central Peru. Thus, the scattered remnants of Holocene emerged shorelines all along the 2500 km are interpreted as evidences of a past high sea stand, which reached about 2 or 3 m above the present datum.

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