QUATERNARY MARINE TERRACES ON THE PERUVIAN COAST AND RECENT VERTICAL MOTIONS

Luc ORTLIEB* & José MACHARE**

* Mission ORSTOM au Pérou, Apartado 18-1209, Lima 18, Pérou

** Instituto Geofísico del Perú, Apartado 3747, Lima 100, Pérou

Résumé

Un réexamen critique de l'ensemble des témoins laissés par les hauts niveaux marins interglaciaires le long de la côte péruvienne est nécessaire pour reconstituer l'histoire des mouvements verticaux ayant affecté cette marge active au cours des deux derniers millions d'années.

Key words: Neotectonics, Vertical movements, Quaternary chronostratigraphy, Sea-level, Marine terraces, Coastal Peru.

Introduction

Paleo-sea level studies provide valuable data for the interpretation of vertical motions experienced by coastal areas, particularly during the last 1-2 M.y. As marine terraces are relatively well-preserved in the arid coastal Peru, they have been observed by many authors, but were seldom thoroughly studied. Moreover, the discrimination between the tectonic and "eustatic" factors controlling the present-day elevation of Quaternary paleo-shorelines has remained a puzzling problem for many authors (e.g. see discussions in Tosdal et al., 1984; Laharie, 1985; DeVries, 1986). Thus, it is time to re-examine the whole Peruvian marine terrace data, in the light of the recent progress made in the interpretation of Pleistocene sea level fluctuations and in the chronostratigraphic analysis of paleoshorelines (Ortlieb, 1987, 1990).

Through this review of the main sequences of Quaternary shorelines, the Peruvian coast will be divided into four segment: the northern (from Tumbes to Chiclayo), north-central,

south-central (from Paracas to Yauca), and southern regions.

The northern coast

The Máncora, Talara, Lobitos and Salina "tablazos" are wide Quaternary marine terraces extending along the northern coast of Peru (Bosworth, 1922). Recently, DeVries (1984, 1986, 1988) modified the Plio-Quaternary chronostratigraphy of the area by redefining the Máncora tablazo as a thin littoral deposit overlying a new Taime Fm.. The Taime Fm. is assigned a Pliocene age and the Máncora tablazo deposits are interpreted to be earliest Pleistocene (DeVries, 1986, 1988). Besides, this author recognized an additional ("Lower Máncora") tablazo, intermediate between the Máncora and Talara terraces.

Morphostratigraphic criteria strongly suggest that the Lobitos tablazo was formed during the early last interglacial high sea stand (Isotope substage 5e, ca. 120 ka), and not during the 40 ka or 80 ka high stands as once envisioned by DeVries (1986). The Lower Máncora and Talara terraces were formed during some of the Middle Pleistocene high sea stands.

A complex pattern of Quaternary vertical deformations characterized the northwesternmost Peruvian coast, and involved altogether some active faulting, an older local uplift centered on the Cabo Blanco area (max. elevation of the Máncora tablazo at +300 m), and a younger, more regional, uplift motion with an estimated mean rate of 0.15-0.20 $m/10^3y$. The last mentioned uplift, which was slightly stronger in the north (north of Máncora) than in the south (Paita-Bayovar), is probably linked to some deep-rooted crustal phenomena associated to the subduction of the Carnegie Ridge.

Five (?) Pleistocene high sea level stands were registered at about +10, +50, +70, +90, and +170 m (Sebrier, 1978) as small staircased abrasion platforms on the Illescas headland (Bayovar). These marine terraces are located on a faulted, southwards tilted, block. The correlation between these terraces and the above-mentioned tablazos is yet pending, except for the lowest terrace (+10 m/Lobitos).

Emerged Holocene strandplains and beach ridge sequences, preserved along low-relief coastal areas of the northern coast ("Salina plains") were probably favored by a slow ongoing regional uplift. Though, such coastal features which have sometimes been cited as evidence of repeated (coseismic) uplift motions, are now interpreted as resulting from late Holocene El Niño oceanographic anomalies (Ortlieb & Macharé, 1989; Ortlieb et al., 1989).

The central coast

From Chiclayo southwards for some 900 km, no emerged Pleistocene shoreline has been described, although remnants of Holocene shorelines are commonly found at up to a few meters above MSL. This lack of Pleistocene marine terraces is generally considered as an evidence for subsidence (e.g. Macharé et al., 1986). Nevertheless, the numerous emergent Holocene coastal features along the central Peruvian coast suggest that the area is not currently experiencing subsident

motions (Ortlieb & Macharé, 1989). Additional studies along this coastline should elucidate whether the area has really been subsiding in the last 2 M.y., and what are the relationships between the distinct tectonic regimes prevailing in the continental margin (with its actively subsiding basins) and the neotectonic comportment of the onshore coastal area.

The south-central coastal segment

The most complete sequence of Plio-Quaternary marine terraces from South America, which includes more than 20 abrasion platforms, is located near San Juan Marcona (Broggi, 1946; Legault, 1960). In spite of the good preservation conditions of the landforms and of the fossil remnants, the age determination of these marine platforms is still actively debated. For instance, in the series of 13 staircased terraces at Cerro del Huevo, an isotope substage 5e age has tentatively been assigned to the +148 m shoreline (Hsu & Bloom, 1985), the +90 m shoreline (Macharé, 1987), and the +65 m shoreline (Hsu, 1988; Hsu et al., 1989). The available geochronological data from San Juan terraces include aminoacid racemization analyses, as well as ESR (electron spin resonance), ^{14}C and Th/U measurements (Hsu, 1988; Hsu et al., 1989). Hopefully, further geochronological analyses presently under-process (at Geotop lab., Univ. du Québec à Montréal, in collab. with C.Hillaire-Marcel and P.Pichet) will contribute to unravel several of the remaining uncertainties regarding the chronology of this exceptional record of late Pliocene to Holocene sea level oscillations.

According to the chronostratigraphic interpretations of the lower terraces of the San Juan area, estimations of mean uplift rates for the last few hundred thousand years vary between 0.47 $m/10^3y$ (Hsu, 1988) and 0.70 ($\pm$ 0.05) $m/10^3y$ (Macharé, 1987). In any case, these are the highest uplift rates measured on the Peruvian coast, and they are closely related to the subduction of the aseismic Nazca Ridge (Macharé & Ortlieb, this volume). As the highest marine terrace of the San Juan sequence (+780 m elevation) is assigned an upper Pliocene age (on paleontological evidence, DeVries in: Macharé, 1987), it may be assumed that the maximum amount of Quaternary uplift has been of the order of 700 m, and thus that the over-all mean uplift rate was of the order of 0.40 $m/10^3y$ in the last ca. 1.8 M.y.

At less than 50 km south of San Juan (Sacaco Basin), the uplift motions have been much weaker, since earliest Pleistocene fossiliferous marine beds are found at a +200 m maximum elevation (de Muizon & DeVries, 1985). In Yauca-Palpa area, a set of numerous Pleistocene beach ridges which apparently document most of the Pleistocene high sea stands, is presently under study.

The southern coast

The southern part of the Peruvian coast (Chala-Tacna) was relatively favorable to the preservation of uplifted marine terraces, that can be observed at varying elevations between +10 and +200 m. Two areas, near Chala and Ilo-Ite,

which show series of staircased platforms with associated fossiliferous coastal sediments, were selected for preliminary geochronological analyses (U-series and aminostratigraphy, in collab. with Geotop lab.).

At Chala, a sequence of eight marine terraces, preserved between +20 and +300 m, had been interpreted as resulting from the combination of four Pleistocene transgressive cycles and five tectonic pulses (Laharie, 1970, 1985), but it is most probable that each platform was eroded during a distinct interglacial high sea stand. The first aminostratigraphic results obtained in Chala area indicate that several coastal deposits (but not all) that crop out at +25/+30 m correlate with the last interglacial maximum. Though, the highest remnants of the substage 5e paleoshoreline may be found at up to +50 m.

At Ilo and Ite, incomplete marine terrace data previously provided some hazardous interpretations which lead their authors to underestimate the recent uplift motions: Tosdal et al. (1984) overestimated the age of the low terraces (erroneously attributed to the Early Pleistocene), while Hsu (1988) inferred from some aminoacid analyses that the deposits of the last three interglacial maxima were in stratigraphic superposition. New radiometric and aminostratigraphic results assess a substage 5e age to the well-developed Pampa del Palo terrace (+20 m) and indicate that several late Middle Pleistocene high sea stands were registered at distinct elevations up to at least +70 m (Ortlieb et al., in prep.).

References

Bosworth T.O. (1922)- Geology of the Tertiary and Quaternary periods in northwestern part of Peru. MacMillan, London. 346 p.

Broggi J.A. (1946)- Bol. Soc. Geol. Peru, 24, 3-24.

DeVries T. (1984)- Bol. Soc. Geol. Peru, 73, 1-13.

DeVries T. (1986)- The geology and paleontology of tablazos in NW Peru. PhD, Ohio State Univ., 1080 p.

DeVries T. (1988)- J. South. Amer. Earth Sci., 1, 121-136.

Hsu J. (1988)- Emerged Quaternary marine terraces in southern Peru: sea level changes and continental margin tectonics over the subducting Nazca Ridge. PhD, Cornell Univ. 310 p.

Hsu J. & Bloom A.(1965)- Geol. Soc. Amer. Abstr. Progr., 17 (7), 614.

Hsu et al. (1989)- Quatern. Sci. Rev., 8, 255-262.

Laharie R. (1970)- Ier Congr.Latinoamer.Geol.(Lima), 6, 145-157.

Laharie R. (1985)- Bull. Inst. Franç. Et. Andines, 14, 19-47.

Legault R.Z. (1960)- Preliminary study of marine terraces in the Marcona-San Juan area, Southern Peru. Univ. Michigan (unpubl.ms.). 23 p.

Macharé J. (1987)- La marge continentale du Pérou: régimes tectoniques et sédimentaires cénozoïques de l'avant-arc des Andes centrales. Thèse Doct.Sci., Univ. Paris-Sud, Orsay. 391 p.

Macharé J., Sébrier M., Huaman D. & Mercier J.L. (1986)- Bol. Soc. Geol. Peru, 76, 45-77.

Muizon C. de & DeVries T. (1985)- Geol. Rundsch., 74, 547-563.

Ortlieb L. (1987)- Néotectonique et variations du niveau marin au Quaternaire dans la région du Golfe de Californie, Mexique. Thèse Doct.-ès-Sci.,Univ. Aix-Marseille II, Et. & Thèses ORSTOM,779+257 p.

Ortlieb L. (1990)- ms submitted to Global Planet. Changes.

Ortlieb L. & Macharé J. (1989)- INQUA Neotect. Bull., 12, 83-84.

Ortlieb L., Macharé J., Fournier M. & Woodman R. (1989)- Bol. Soc. Geol. Peru, 80, (in press).

Sebrier M. (1978)- La tectónica reciente de la zona de Bayovar. Contrib. Inst.Geofis.Perú, 78-01. 29 p.

Tosdal R.M., Clark A.H. & Farrar E. (1984)- Geol. Soc. Amer. Bull., 95, 1318-1332.