RECENT VERTICAL MOTIONS AND THE SUBDUCTION OF THE NAZCA RIDGE, CENTRAL COAST OF PERU

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Resumen

La deformación causada por la subducción de la Dorsal de Nazca se manifiesta por el levantamiento cuaternario de la zona costera entre Pisco y Lomas, que llega a 1000 m. Los modelos físicos de deformación podrían ser mejorados mediante la inclusión de nuevos datos cinemáticos y geocronológicos.

Key words: Neotectonics, Aseismic ridges, Marine terraces, Coastal Peru.

Background

A decrease of seismic activity, inhibition of arc volcanism and coastal geomorphic modifications, are reported among the main effects of the subduction of aseismic ridges (Vogt et al., 1976).

The Nazca Ridge is a major, aseismic and volcanic, topographic high that is being subducted beneath the Andes of south-central Peru, between 14° and 16° S latitude. Several tectonic and magmatic effects of this subduction have already been recognized; these include the cessation of the Cenozoic arc volcanism to the north and a lowering of the seismicity level (Barazangi & Isacks, 1976; Mégard & Philip, 1977; Cross & Pilger, 1982), and a strong coastal uplift as revealed by long sequences of Plio-Quaternary shorelines (Teves, 1975; Macharé & Huamán, 1982; Hsu, 1988). Some preliminary modelling of the neotectonic impact of the subduction of the ridge on the coastal region has been attempted (Moretti, 1982; Hsu, 1988) but still require improvements before a clear understanding of the regional geodynamic evolution is obtained.

The coastal uplift: a consequence of the Nazca Ridge subduction

Between 5°S and 16°S, the Peruvian forearc region has evolved under marine conditions and stayed below sea level in Cenozoic times. Meanwhile, south of 16°S, the inland part of the Peruvian margin (particularly the Coastal Cordillera and Moquegua basin) remained emerged during most of the Tertiary and the Quaternary (Macharé et al., 1986). Therefore, the recent uplift observed in the coastal segment between 14°S (Pisco) and 16° (Lomas) may be considered as abnormal, and should be interpreted as closely linked to the subduction of the Nazca Ridge. Actually, it can be established that the uplift is spatially coincident with and genetically related to the Nazca Ridge.

Modelling of the deformation

To date, two models have been proposed to explain the coastal uplift as an effect of the subduction of the Nazca Ridge. The first one is a simple geometric model based on the "similarity" between the shape of the Nazca Ridge above the ocean floor and the topographic dome formed by the coastal region (Hsu, 1988). This model did not take into account any physical parameter constraining the basic rheologic behavior of the overriding plate.

Earlier, Moretti (1982) had tested a static model in which the Nazca Ridge is considered as a density heterogeneity which produces a vertical upwards stress field of 0.35 kb on a 200 x 400 km rectangular-shaped surface below an elastic homogeneous continental plate. The best adjustment of Moretti's model predicts an oval dome-shaped uplift extending over 500 km along the coast which amounts to a maximum amplitude of 1,100 m. The results of this model strongly depend on two parameters: the ridge width and the flexural rigidity of the overriding plate. It would be greatly improved by introducing a visco-elastic component (instead of a perfectly elastic response), and by taking into consideration the velocity of the southeastwards migration of the ridge along the margin.

The relative motion of the Nazca Ridge and the margin

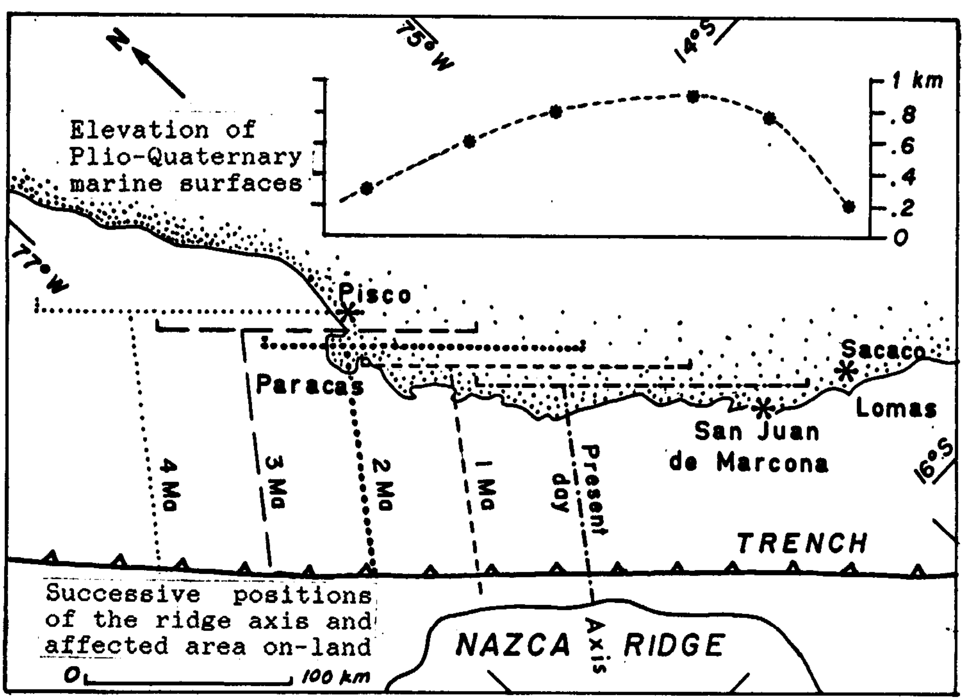
Because of the N080° azimuth of the Andean convergence (Minster et al. 1974), the Nazca Ridge (mean strike= N040°) is obliquely subducting under the Peruvian margin (mean strike= N145°). Thus, it may be established that with a convergence rate of 80-100 km/My (Pilger 1983) the ridge has been scanning the margin southeastwards with a mean velocity of 60 ±7 km/My. From these kinematic reconstructions, it is inferred that the Nazca Ridge began to directly affect the 14°-16°S coastal segment by 4 My ago.

Among other dynamic considerations which have not been included in previous modelling, it is important to note that the projection of the present-day ridge axis onto the continent does not exactly coincide with the area which registered the highest uplift rates (San Juan de Marcona), as assumed by Hsu (1988), and that there are evidences that, in the northern part of the coastal segment, some areas which have been previously uplifted (in late Pliocene-middle Pleistocene) are now experiencing subsident motions.

Amount and rates of uplift

In order to determine the main parameters of the deformation (shape, rates, timing), it is necessary to reconstruct the movements experienced along several coastal transects, and if possible at different time scales. This goal is not yet entirely achieved, but some new elements are being gathered. The main difficulty is to assess accurate correlations in time and space between localities referable to a given horizontal datum (sea-level).

The geometric distribution of the highest marine surfaces eroding the Coastal Cordillera, can be used to depict the long-term deformation registered by the area in the last few million years. The problem is that these abrasion surfaces, which are interpreted as remnants of the last marine invasion, are diachronic. Near the northern extremity of the Pisco Basin (Paracas), the sea began to regress by middle Pliocene, while more to the south (Sacaco), the last regression is considered to have occurred in the early Pleistocene (Muizon & DeVries, 1985; Macharé, 1987). Though, by trying to take into consideration these age differences, we propose an elevation vs. latitude plot of these well-developed surfaces (figure). This plot displays an asymetrical dome shaped



deformation. The asymetrical character is partly due to the fact that the northern slope actually reflects subsident motions superimposed on the previous uplift. The maximum net uplift is observed ahead (southwards) of the migrating ridge axis.

For the shorter term deformations, correlation studies on remnants of Pleistocene sea level highstands should play a major role. Nevertheless there are discrepancies regarding the age of these paleo-shorelines, and thus in the estimates of uplift rates in the last few hundred years. One of the latest chronostratigraphic interpretations of the staircased terrace sequences, which relied on a tentative correlation with the peaks of the deep-sea core $\delta^{18}O$ curves of Shackleton & Opdyke (1973) and Imbrie et al. (1984), led to a maximum estimate of 0.7 mm/y of mean uplift motion in the last 0.5 My (Macharé, 1987). In another study including aminoacid and radiometric measurements on numerous fossil shells, Hsu (1988) proposed uplift rates varying from 0.1 mm/yr (in the northern and southern ends of the region) to 0.47 mm/yr (San Juan de Marcona). On-going research on these terraces should lead to more precise age determinations of the lower terraces, and to a better identification of the last interglacial maximum (Ortlieb & Macharé, this volume).

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