PALEOMAGNETISM OF JURASSIC VOLCANICS AND CRETACEOUS PLUTONIC ROCKS FROM COASTAL SOUTHERN PERU. IMPORTANCE OF ROTATIONS IN THE ARICA DEFLECTION.

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Résumé

Une étude paléomagnétique détaillée (51 sites) des unités volcaniques du jurassique inférieur et de roches intrusives jurassique à crétacé inférieur de la zone côtière sud-péruvienne (de 16°S à 18°S) a été entreprise afin de tester l'hypothèse d'une déformation oroclinale des Andes centrales. La formation Chocolate (jurassique inférieur) a enregistré une réaimantation avec une déclinaison paléomagnétique d'environ 330° . L'aimantation primaire des unités volcaniques ainsi que les résultats sur le batholite d'Aréquipa indiquent des rotations antihoraires plus importantes d'environ 50 à 60°.

Key Words: Paleomagnetism, Tectonic rotations, Andes

Introduction

Geological evidences for allochtonous terrane in northern Peru and Western coastal Ecuador have recently been confirmed by paleomagnetic studies [Mourier et al., 1988; Roperch et al., 1987]. On the contrary, the numerous paleomagnetic studies undertaken in the central Andes have not shown any evidence for the occurrence of allochtonous terranes [Palmer et al., 1980a,b; Heki et al., 1984; May and Butler, 1985]. However, these studies have suggested some angular discrepancies between Peru and Chile that led Kono et al. [1985] to propose a large oroclinal bending of the Andes. This interpretation has recently been challenged by Beck [1988], who suggests in situ block rotations as a result of different directions of convergence between the oceanic plate and the overriding continental crust. On the other hand, Isacks [1988] suggests that the high elevation of modern Central Andes and the large width of the altiplano as well as the thickness of the crust is a consequence of crustal shortening. A model allowing various amount of shortening with a maximum in the central Andes of between 250 and 425 km indicates the possibility of relative forearc rotation of 15° to 25° between Peru and Chile [Isacks, 1988].

We have undertaken a paleomagnetic study of Jurassic volcanism and lower Cretaceous intrusions in coastal southern Peru where the strike of the andean structures may suggest the most anticlockwise rotation in the hypothesis of a strong oroclinal bending in the Andes.

Geology and Paleomagnetic sampling (Figure 1)

The Southern Coastal Peru area, between 14°S and 18°S, is limited to the east by the overthrust system of the Chincha-Lluta [Vicente et al., 1979, Vicente, 1985]. The outcrops of the Precambrian Arequipa massif are confined west of this limit. The Chocolate volcanic formation is unconformably deposited on the precambrian basement. The age of this formation is not clearly established but it overlies the lower Permian Machani formation [Salinas, 1987] and a lower-Sinemurian faunal association is recorded at the top of the formation [Vargas, 1970; Vicente, 1981, Vicente et al., 1982]. Therefore, the age of the Chocolate formation is limited to the Upper Permian-Hettangian interval. Near Chala, Ilo and La Yarada, the base of this thick formation (>3000m) begins with conglomerate beds with intercalated acid volcanic horizons. The upper part is typically caracterized by andesitic volcanic breccias with interbedded marine and continental sedimentary sequences and basaltic to andesitic flows. At La Yarada, the Chocolate unit is overlain by the Guaneros Formation, a shallow marine serie that represents eastward lateral variation of the Bajocian Socosani Formation. The Bathonian to tithonic Yura Group [Jenks, 1948; Benavides, 1962; Vargas, 1970; Vicente et al., 1981; Vicente, 1982] are not recorded in the Southern Coastal Peruvian area and the Jurassic formations are unconformably overlain by the

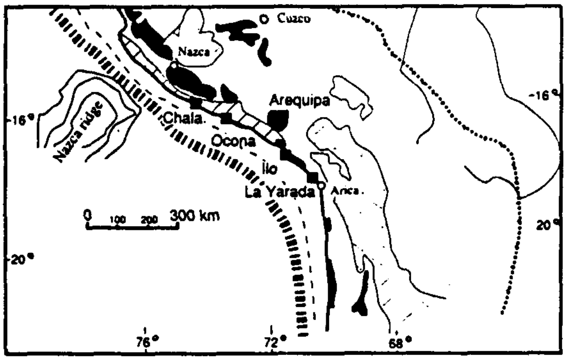

Fig. 1 : *Simple geological and paleomagnetic sampling map*

volcanic Toquepala formation of paleocene age [Laighlin et al., 1968; Bellon and Lefèvre, 1976; Estrada, 1975]. Near Ocona, where the Jurassic sequence is not deposited or not preserved, localised granodiorite plutons are intruded during the triasic times (205Ma, Stewart et al., 1974]. Near Ilo, the Chocolate Formation is intruded by the gabbro-monzotonalite rocks of the Punta Coles and the Ilo super-units respectively 196-182 Ma and 150 Ma old [Mukasa, 1986; McBride, 1977]. The main magmatic activity is recorded by the coastal batholith. In the Arequipa segment, the early phases of the magmatic activity are dated at 105 Ma and the last ones at 61 Ma [Mukasa, 1986]. Four Super-units are distinguished: the early gabbros (105-101 Ma], the Tiabaya superunits (84-78 Ma.), the Linga-Yarabamba S-U (70.5-62.1 Ma) and the Cerro Verde quartz Monzonite (61 Ma) [Mukasa, 1986].

The paleomagnetic sampling was carried out in six different localities hundreds kilometers apart along the southern coast of Peru with 51 paleomagnetic sites and a total of 470 cores. Near Chala, eleven sites were sampled in the Chocolate Jurassic volcanic formation, one site of red sandstone interbedded in the volcanics and two sites in a plutonic intrusion a few kilometers north of Chala. Further south, near the locality of Ocona, two sites were drilled in a plutonic intrusion, possibly of upper triasic age. Several sites were drilled in different units of the batholith from the Arequipa area. Upper Jurassic and lower cretaceous sediments were also sampled at four sites north of Arequipa. Five sites of the Chocolate formation were sampled near Ilo on the coast and 3 sites were drilled in nearby intrusive formations. Fourteen sites were collected in the area of La Yarada, west of Tacna.

It was difficult to recognize if sills and dikes are contemporaneous of the volcanics of the Chocolate formation that they intrude.

Paleomagnetic results

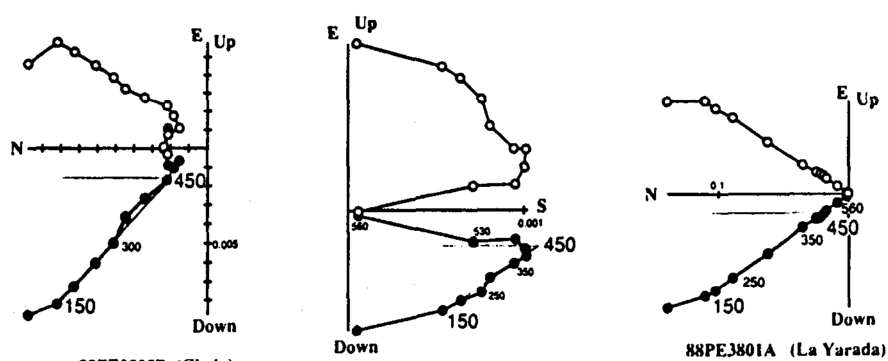

Fig.2 : *Examples of thermal demagnetization showing a secondary magnetization between 150 and 450°C. Open circles correspond to the projection of the vertical component, solid circles correspond to the horizontal and the shaded area highlights the deviation of the declination from the present day north.*

Because of the existence of hematite whose magnetic properties were clearly recognized during laboratory experiments, progressive thermal demagnetization proved to be most superior in demagnetizing some of the volcanic units than alternating field techniques and it was generally very efficient in isolating components of magnetization with different unblocking temperatures.

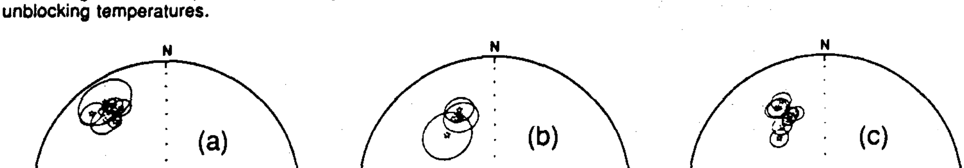

Fig.3 : *Equal-area projections of the mean-site directions with their 95% confidence angle for the secondary magnetization observed at Chala (a), Ilo (b) and La Yarada (c).*

A magnetic overprint was observed in several volcanic units in Chala, Ilo and La Yarada and examples of demagnetization diagrams are shown on figure 2. This secondary remanence has unblocking temperature between 150-450° and it is often the only component of magnetization left in a sample. Mean-site directions are shown in figure 3. This magnetization was acquired after deformation of these units because the tilt correction significantly increases the dispersion of the data.

A primary component of magnetization with high unblocking temperature above 500°C was isolated in volcanics at several sites near Chala and Ilo. A primary magnetization was also identified in different intrusives units. Mean-site results are shown on figure 4

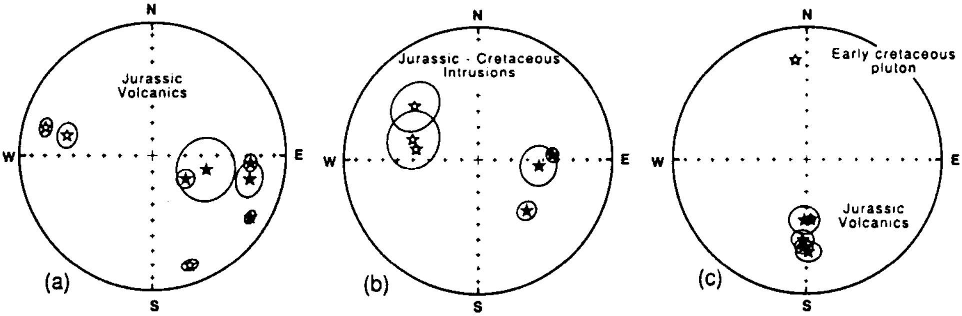

Fig.4 : *Equal-area projections of the mean-site directions with their 95% confidence angle for the primary magnetization observed at Chala (a), Ocona-Arequipa(b) and Ilo (c).*

Both normal and reversed polarities are found and are almost antipodal; this constitutes a positive reversal test which demonstrates that these paleomagnetic directions do not correspond to anomalous magnetic field behavior. No tilt correction was applied to the intrusive rocks. Large counterclockwise deviations of the declination is observed at Chala and in intrusives rocks near Ocona and Arequipa. On the contrary, no deviation from the present day geographic axis is observed at Ilo, but because the secondary magnetization has a westerly declination, this is an evidence for local clockwise rotation prior to the acquisition of the secondary magnetization.

Discussion

Relative tectonic rotations of the central Andes with respect to stable South America (SA) can only be assessed by comparing the observed paleomagnetic direction with the one expected for SA. To do this, the knowledge of the age of the magnetization and an accurate paleomagnetic apparent polar wander path (APWP) for SA are necessary. The APWP of SA is poorly defined but it has been within 15° around the present geographic axis since 200Ma. The problem of an accurate APWP has often been neglected in interpretations of previous paleomagnetic results. Clockwise or counterclockwise rotations of 10-15° cannot be really demonstrated as long as the uncertainties in the APWP are not reduced. Only direct comparison of paleomagnetic results from rocks of the same age north and south of the Arica hinge may improve the accuracy of relative rotation models between Peru and Chile.

The secondary magnetization observed in the Chocolate volcanics is not easily dated. The major thermal event corresponds to the intrusion of the batholith and the last event of deformation is the Chincha-Lluta overthrust of santonian age [Vicente, 1985]. Thus it seems reasonable to give an upper cretaceous age to this remagnetization. The mean declinations vary from 325 to 331° which leads to a conservative estimate of counterclockwise rotations of about 20°. This rotation is consistent with a large shortening in the central Andes.

The primary magnetization indicates that about 50° to 60° counterclockwise rotation occurred from Chala to Arequipa. Since only about 20° is recorded by the post remagnetization, this means that 30 to 40° counterclockwise rotation had occurred in cretaceous time, possibly at the time of the Chincha-Lluta overthrust. On the other hand, results from Ilo suggest local clockwise rotation.

We are starting a paleomagnetic survey of Bolivia and we hope that additional paleomagnetic data from the inner and eastern part of the chain will provide a better understanding of the pattern of tectonic rotations in the Andes.