A PALEOMAGNETIC STUDY OF THE ALTIPLANO

Pierrick Roperch[1], Michel Fornari[2] and Gérard Hérail[3]

(1) ORSTOM et Laboratoire de Géophysique, Campus de Beaulieu, 35042 Rennes, Cedex
(2) ORSTOM, C.P. 8714, La Paz, Bolivia
(3) ORSTOM, Casilla 53390, Correo Central, Santiago 1, Chile

RÉSUMÉ: Les résultats paléomagnétiques disponibles pour le Mésozoique et le Cénozoique indiquent des rotations antihoraires au Pérou et horaire au Nord Chili. Cette étude présente des résultats obtenus sur l'Altiplano bolivien (1) dans une séquence volcanique miocene du sud-Lipez, (2) dans des sédiments tertiaires de la formation Tiwanaku et Kollu Kollu à l'ouest de LaPaz et (3) dans les formations permo-carbonifère au niveau du lac Titicaca.

KEY WORDS: Palaeomagnetism, Tectonic Rotation, Bolivian Altiplano, Orocline

INTRODUCTION

Previous paleomagnetic results (Heki et al., 1983, Kono et al., 1985, Macedo et al., 1992, Roperch and Carlier, 1992) from Mesozoic rocks from coastal Peru and northern Chile have suggested that the present shape of the Andean chain is the result of oroclinal bending. A model of in situ block rotations associated to oblique convergence is an alternative interpretation of the paleomagnetic data (Beck, 1988; Dewey and Lamb, 1990).
In order to better understand the pattern of tectonic rotations observed in the Central Andes, we have undertaken a paleomagnetic study of the Bolivian Altiplano. The structure of the Altiplano is complex with fold-thrust belts and wrench-fault zones (Sempéré et al, 1990). Thus, the paleomagnetic sampling was made in several structural zones. Miocene volcanics and sediments were sampled in the southern part of the Lipez basin. A paleomagnetic sampling was undertaken in Eocene red sandstones from the Camargo syncline. The Oligo-Miocene Tiwanaku red beds formation was sampled south-west of La Paz and four sites were drilled in the Miocene sediments of Kollu-Kollu formation. Finally we will present preliminary results obtained in Permian-Carboniferous rocks (Copacabana limestone and Permian red-beds) which outcrop near the Lake Titicaca.

PALEOMAGNETIC RESULTS

About 80 sites were sampled in Bolivia. At each site about 10 cores were collected with a portable gasoline core drill. The magnetization of all samples from volcanic units was measured with a spinner magnetometer while a cryogenic magnetometer was used for most sedimentary units. The characteristic remanent magnetizations were determined after stepwise (10 to 15 steps) progressive thermal or alternating field demagnetizations.
The results will be presented for each region shown on Figure 1.

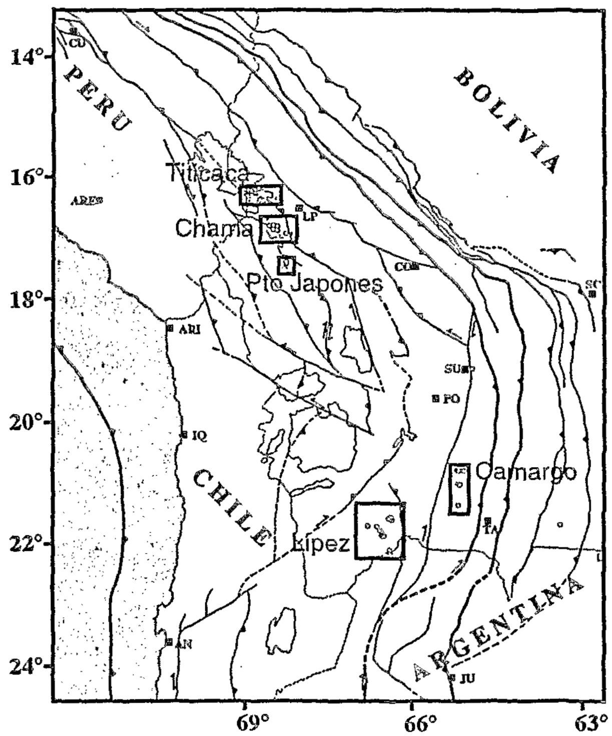

Figure 1: Paleomagnetic sampling map in Bolivia (structural sketch from Sempere et al., 1990)

A) Lipez

Thirty two sites were sampled in tertiary units south of the locality of San Pablo de Lipez. Out of these 32 sites, 16 sites correspond to the Miocene Rondal volcanics dated by K-Ar to about 20 Ma (Bonhomme, unpublished results).

The characteristic magnetizations were easily identified in the Rondal formation (Figure 2a). Directions of reversed polarity (positive inclination, south-west declination) are found at 13 sites and a normal polarity is observed at two sites. An intermediate direction is observed at one site and is rejected from the mean calculation. The mean direction (Declination=219°; Inclination= 38°, $\alpha95$=11°) is rotated about 40° clockwise from the expected direction.

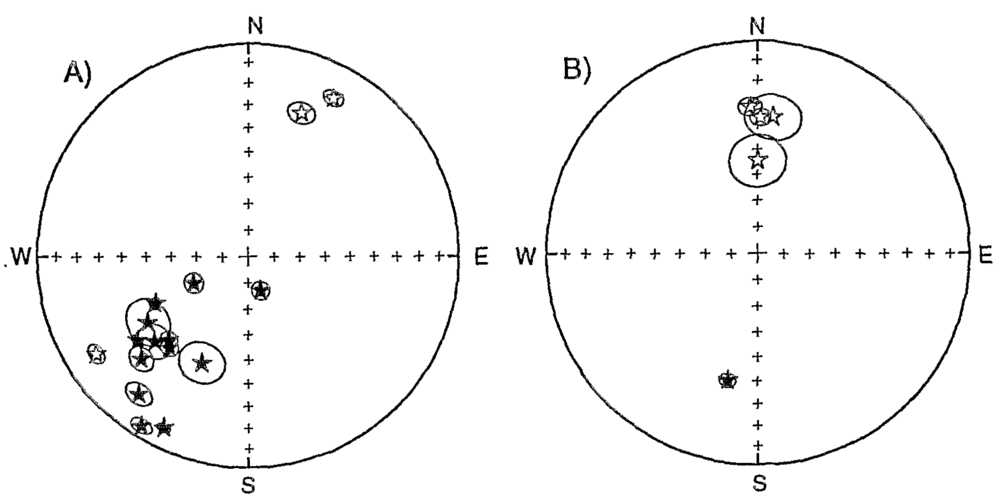

Figure 2: Equal area projection of mean-site paleomagnetic results with associated angle of confidence at 95% for the Lipez area. (A) Miocene Rondal volcanics, (B) sediments. Open symbols correspond to negative inclinations and solid symbols to positive inclinations. All data are tilt-corrected.

Results from sediments are only available at 5 sites located north of the Guadalupe area where the volcanics were sampled. The declinations in the sedimentary sites are not deflected clockwise as it was observed in the volcanics. The structural and stratigraphic relations between the Guadalupe and San Pablo areas which are 20 km apart still need to be clarified for an accurate interpretation of the discrepancy between the two sets of paleomagnetic data in south-west Bolivia.

B) Camargo syncline
Eight sites (85 samples) were drilled in the Eocene red sandstones. A complex remanent magnetization is observed possibly due to several phases of diagenetic formation of hematite. Thus, no characteristic mean paleomagnetic result is available for this area.

C) Pto. Japones and Chama
Four sites (44 samples) were sampled in the Kollu Kollu formation in the area of Pto Japones and 13 sites (148 samples) were obtained in red beds from the Tiwanaku and Coniri formations. Normal and reversed magnetizations are found after thermal demagnetization (Figure 3a,b). The mean-site paleomagnetic directions observed at both localities (Pto Japones, 3 sites: D=162°, I=21°, $\alpha95$=5°) (Chama, 9 sites: D= 167°, I=34°, $\alpha95$=13°) are not statistically different. Thus a mean direction can be computed from all sites (12 sites: D=166°, I= 30°, $\alpha95$=10°).

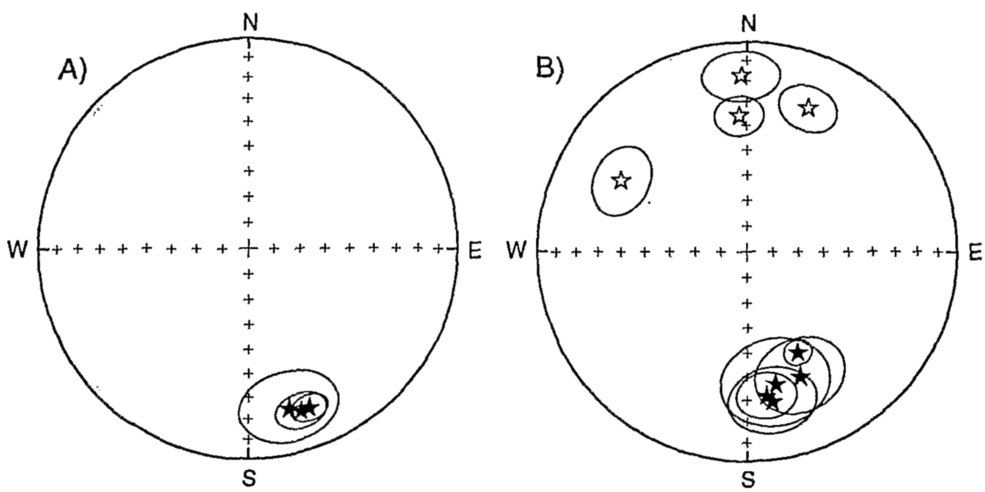

Figure 3: Equal area projection of mean-site paleomagnetic results with associated angle of confidence at 95% for (A) Miocene sediments from Pto Japones locality, (B) Oligo-Miocene red beds of the Tiwanaku formation (Chama locality). Same conventions as in Figure 2

D) Lake Titicaca

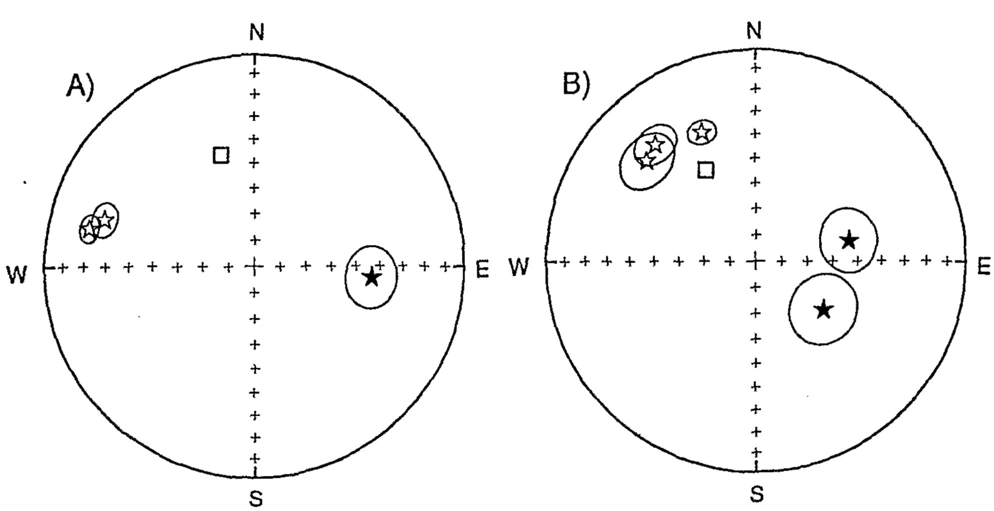

Figure 4: Equal area projection of mean-site paleomagnetic results with associated angle of confidence at 95% for the Titicaca area (A) Upper permian red-beds, (B) Copacabana limestone. The square corresponds to the expected paleomagnetic direction for stable South-America at about 250Ma (A) and 310Ma (B). Same conventions as in Figure 2.

Three sites (41 samples) were sampled in the Permian units near the Tiquina straits and 6 sites (59 samples) were taken in the Copacabana limestone. A soft component of magnetization removed by alternating field demagnetization is often found in the limestone making difficult an accurate determination of the primary magnetization. However the between-site scattering decreases after bedding correction suggesting a primary origin for the magnetization. Normal and reversed magnetizations are found that suggest that the copacabana limestones were deposited before the long-reversed Kiaman superchron and that the permian red-beds postdates the end of the Kiaman. The large counterclockwise deviation of the declinations observed for the Permian sites is not clearly documented by the other Carboniferous sites. The Permian sites are located nearby a major fault and the recorded counterclockwise rotation suggests a sinistral motion along that fault.

DISCUSSION

Few paleomagnetic data from Bolivia have been published. The most significant data are those reported by Mc Fadden (1990). Our result from the Rondal volcanics and the clockwise rotation of about 18° reported from a middle Miocene section at quebrada Honda (McFadden, 1990) demonstrate the existence of clockwise block rotations in southern Bolivia, possibly associated to dextral faults.

In northern Bolivia, the deviation of the mean declination in a late Oligocene-early Miocene section in the eastern Cordillera (Salla locality, McFadden, 1990) is only of -7°. In contrast, our mean result from the Oligocene-Miocene red beds from the Altiplano indicates a deviation of -14°. This result is not different from those reported for tertiary units in Peru, the Ocros dyke swarm (Heki et al., 1985) and the Lima area (Macedo et al., 1992). Although the amount of tectonic rotations is dependent of local structures and a mean paleomagnetic result obtained from several sites in different structural blocks does not imply that the whole area is rotated by the mean paleomagnetically derived rotation, the apparent coherence in the mean paleomagnetic declinations from Lima to La Paz is striking.

In conclusion, the paleomagnetic results obtained during this study confirm the existence of relative rotations between the northern and southern structural blocks that composed the Altiplano.

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