CLOCKWISE ROTATIONS IN NORTHERN CHILE: OROCLINAL BENDING AND IN SITU TECTONIC ROTATIONS?

G. DUPONT-NIVET[1], P. ROPERCH[2,1], P. GAUTIER[1], A. CHAUVIN[1], M. GÉRARD[3] AND G. CARLIER[4]

1 Géosciences Rennes, Campus de Beaulieu, Rennes, France
2 ORSTOM and Universidad de Chile, Santiago, Chile
3 Centre ORSTOM, Bondy, France
4 ORSTOM et MNHN, Paris, France

KEY WORDS: Paleomagnetism, Tectonics, Rotation, Orocline, Chile

INTRODUCTION

The pioneer paleomagnetic work carried by a Japanese team (Kono et al., 1985) did show clockwise rotations of the Chilean forearc, counterclockwise rotations in Peru and evidence for a tectonic origin of the bending of the Central Andes. Later, Isacks (1988) proposed that mountain building in the Central Andes, characterized by differential along-strike shortening, has enhanced the development of the Bolivian orocline (see also Watts et al., 1995). Recently however, some authors have questioned the origin of the rotations, observed mostly in Mesozoic rocks, along the forearc of northern Chile. Forsythe and Chisholm (1994) and Grocott et al. (1994) indicate that clockwise rotations recorded in Jurassic-lower Cretaceous rocks are linked to the sinistral motions along the Atacama fault system during the Early Cretaceous. On the other hand, they discard the possibility that a significant amount of clockwise rotations is associated to oroclinal bending. In contrast, we interpret the general clockwise sense of rotation as evidence for a dextral shear and oroclinal bending effect during the Tertiary.

In this study we report new paleomagnetic results based on an extensive sampling (100 sites) from 22°S to 26°S. During our last fieldwork in February 1996, the paleomagnetic sampling was mostly done in lower Tertiary volcanics east of the Mesozoic arc in order to have a better control on the timing and spatial distribution of the rotations.

PALEOMAGNETIC SAMPLING

The forearc of northern Chile is principally composed by north-south trending features. The coastal magmatic arc with Mesozoic intrusives and volcanics (La Negra formation) is longitudinally cut by the Atacama fault system. The ductile deformation along this fault system is of lower Cretaceous age (Marinovic et al., 1995) and clearly shows a sinistral sense of shear. Some of the faults have been reactivated during the Late Tertiary - Quaternary and they mostly show normal scarps. The late Cretaceous and early Tertiary volcanics outcrop east of the Mesozoic magmatic arc and west of the Domeyko fault system and they usually show little deformation. Most of the Andean deformation in northern Chile is observed across the Domeyko fault system. The tectonic style is complex and involved E-W shortening with successive dextral and sinistral shear (Mpodozis et al. 1993; Reutter et al., 1991).

We sampled the Jurassic La Negra formation near Tocopilla (12 sites), Antofagasta (16 sites) and Taltal (9 sites). Six sites were drilled in Mesozoic intrusives. In the central valley, east of Taltal, we sampled Paleocene-Eocene volcanics. About 200 Km further north, we sampled upper Cretaceous and lower Tertiary volcanics and sediments near Baquedano and Quebrada del Buitre. West of the Salar de

Atacama, we drilled two sections in the Tonel-Purilactis red sandstones and interbedded sills and one site in the Oligo-Miocene Paciencia red beds.

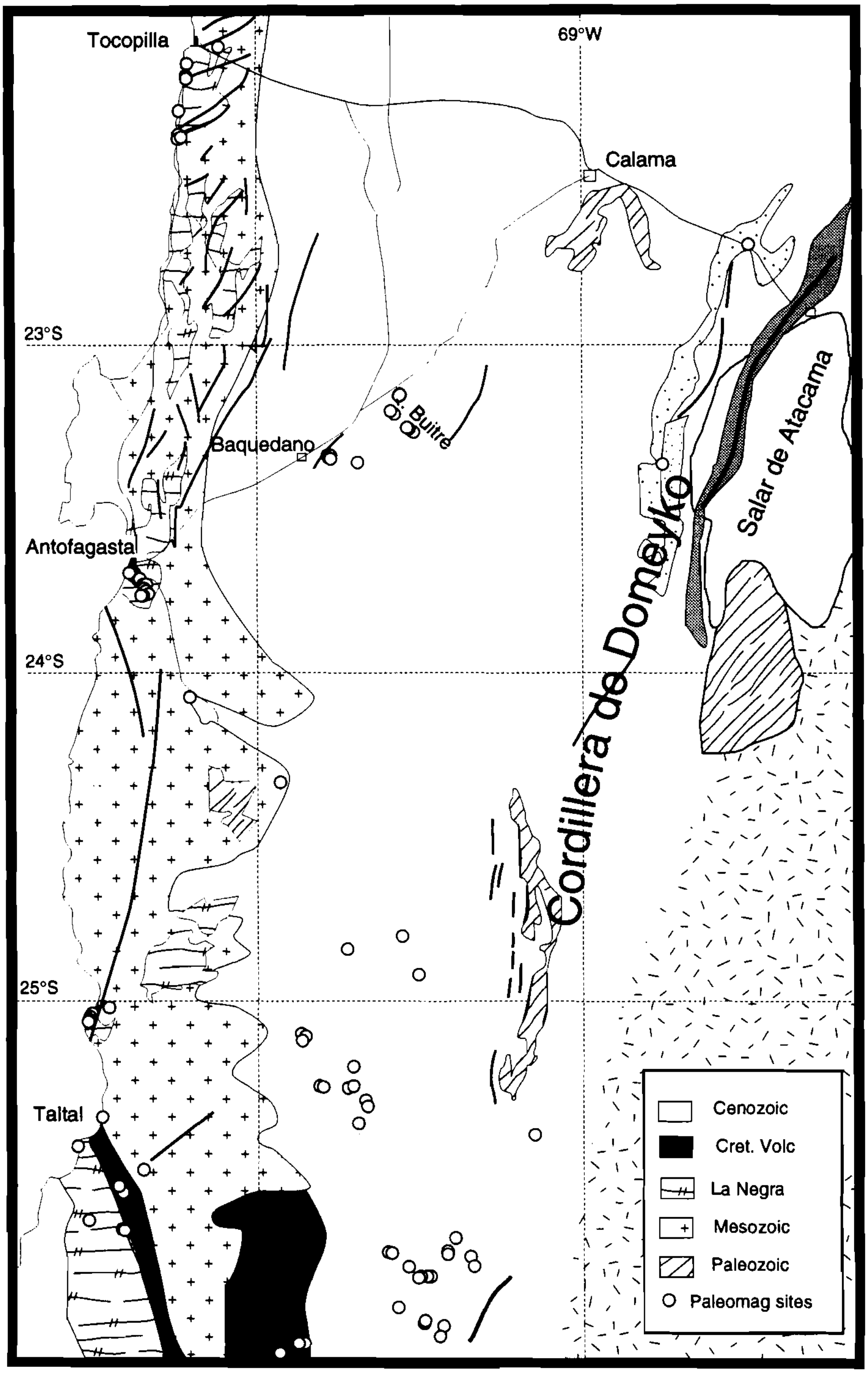

Figure 1: Simplified geological map from northern Chile and paleomagnetic sampling

PALEOMAGNETIC RESULTS

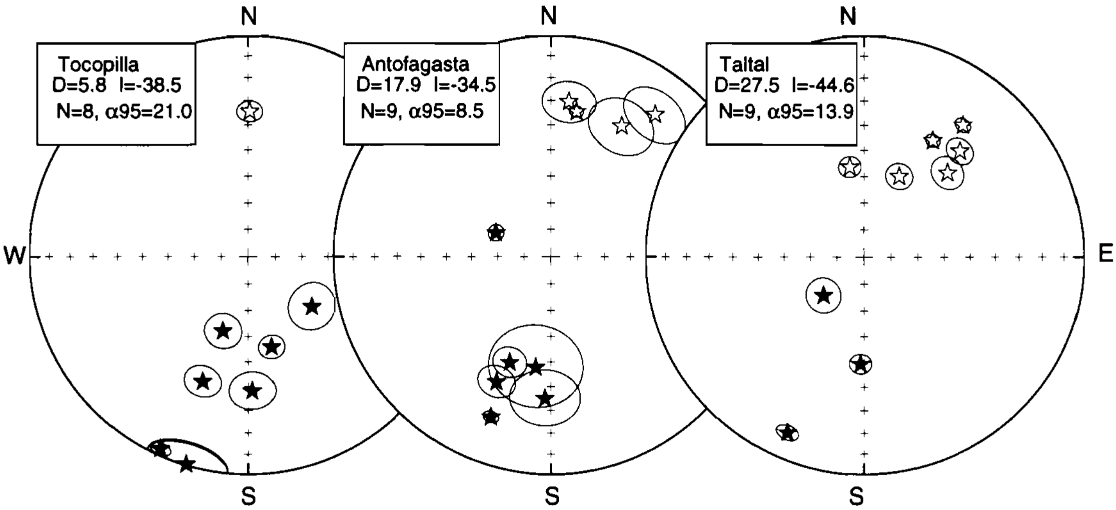

Figure 2: Paleomagnetic results from the Mesozoic arc.

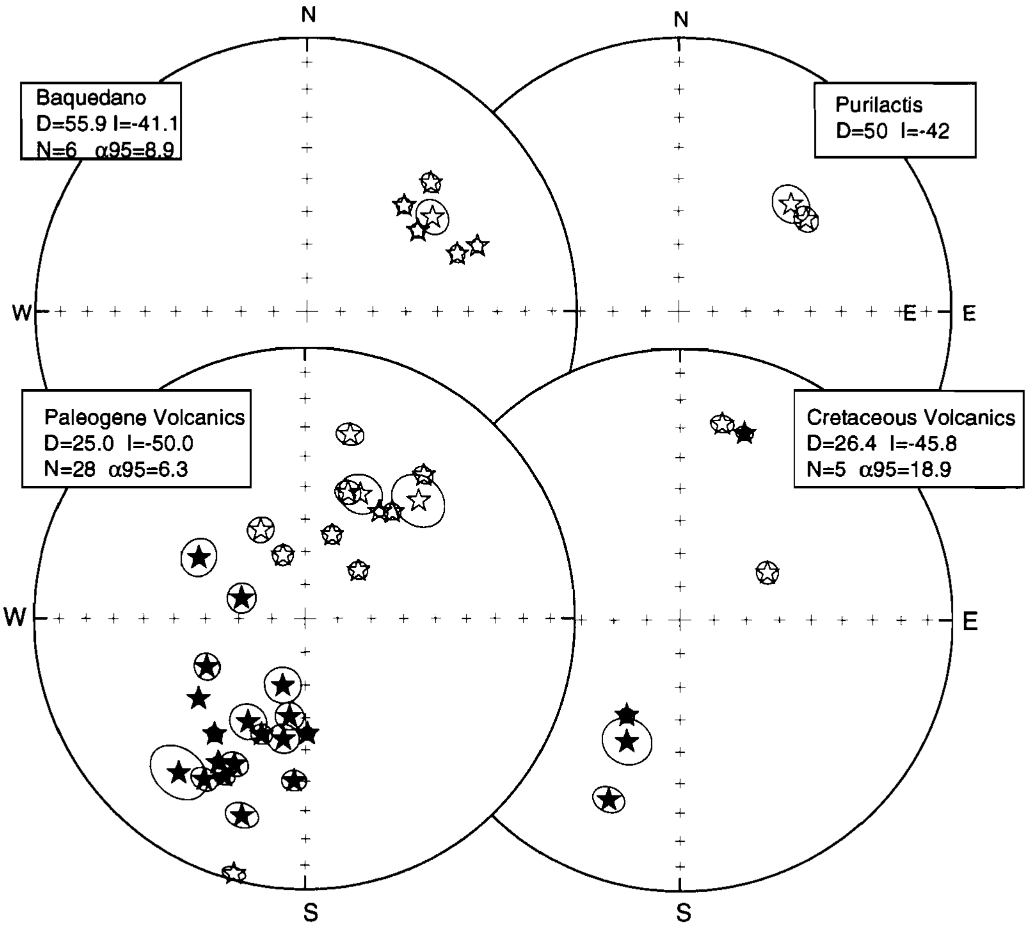

Figure 3. Paleomagnetic results from the area in between the Atacama and Domeyko faults system

The Jurassic volcanics

Magnetic susceptibility is usually high to very high (up to 0.1SI). Multidomain magnetite and maghemite is often the main magnetic carrier and secondary magnetizations are widespread. In the

Antofagasta area, in many cases, normal and reverse polarity magnetizations are found within the same flow. This behavior is likely associated to low temperature metamorphism during burial of the thick volcanic sequence. After detailed thermal and AF demagnetizations we were however able to determine a characteristic magnetization for several sites (Fig. 2).

Upper Cretaceous and Tertiary

Baquedano and Purilactis formation

East of Baquedano, about 70 Km NE of Antofagasta, the characteristic magnetization in the sediments and interbedded lavas corresponds to a remagnetization associated to an oxidizing event of possible hydrothermal origin. This remagnetization is however well defined and in good agreement with the primary magnetization recorded in a ryolitic lava located 10 km east of the Baquedano section. On average these sites record a clockwise rotation of about 60°. We sampled also 5 sites in the Quebrada Buitre but there is a large scatter between the sites. Only one section in the red sandstones and interbedded sills in the Tonel-Purilactis formation gave reliable paleomagnetic results; this section also documents large clockwise rotation (Fig. 2) and this result is in good agreement with a previous study in the same formation and located further north (Hartley et al., 1992).

Central Valley (East of Taltal from 24°45' to 26°)

For all sites, the characteristic magnetization was determined precisely with the majority of the samples showing univectorial magnetizations (Fig.3). After removal of 3 directions which are at more than 2 standard deviations from the mean, the mean declination is 25°. This result demonstrates that clockwise rotations are not restricted to the coastal domain.

Our new paleomagnetic results provide additional evidence for a tectonic process involving large clockwise rotations in northern Chile during the Tertiary. The differential along-strike shortening model of Isacks (1988) implies clockwise rotations during the Late Cenozoic by about 10°. Paleomagnetic results obtained in Bolivia (Butler et al., 1995; Roperch et al, this volume) suggest that the largest rotations occurred before 20Ma. Thus, the difference between the observed and expected (from the Isacks model) rotations emphasizes the importance of early-middle Tertiary tectonics in the structuration of the Central Andes.

Acknowledgments. Discussions about the geology and tectonics of Northern Chile with C. Mpodozis, P. Cornejo and A. Tomlinson have been very helpful to prepare the paleomagnetic field sampling.

REFERENCES

Forsythe, R., and L. Chisholm, 1994. Paleomagnetic and structural constraints on rotations in the North Chilean Coast Ranges, *Journal of South American Earth Sciences*, *7*, 279-295.

Grocott, J., G.K. Taylor, P.J. Treloar, and J. Wilson, 1994. Magmatic arc fault systems and the emplacement of mesozoic plutonic complexes in Northern Chile, *7° Congreso Geologico Chileno, II*, 1360-1364.

Hartley, A., E. Jolley and P. Turner, 1992. Paleomagnetic evidence for rotation in the Precordillera of northern Chile: structural constraints and implications for the evolution of the Andean forearc, *Tectonophysics*, 205, 49-64.

Isacks, B.L.; 1988. Uplift of the central Andean plateau and bending of the Bolivian orocline, *J. Geophys. Res.*, 93, 3211-3231.

Kono, M., K. Heki and Y. Hamano, 1985. Paleomagnetic study of the Central Andes: counterclockwise rotation of the Peruvian block, *J. Geodyn.*, 2, 193-209.

Marinovic, N., I. Smoje, V. Maksaev, M. Hervé and C. Mpodozis, 1995. Hoja Aguas Blancas, *Carta geologica de Chile, 1/250000, Serv. Nat. Geol. Min.*, Vol 70, 150pp.

Mpodozis, C., N. Marinovic, and I. Smoje, 1993. Eocene left lateral strike slip faulting and clockwise block rotations in the cordillera de Domeyko, west of Salar de Atacama, Northern Chile, *second International Symposium on Andean Geodynamics*, 225-228.

Reutter, K.J., E. Scheuber, and D. Helmcke, 1991., Structural evidence of orogen parallel strike slip displacements in the Precordillera of Northern Chile, *Geologische Rundschau, 80*, 135-153.

Watts, A.B., S.H. Lamb, J.D. Fairhead and J.F. Dewey, 1995, Lithospheric flexure and bending of the Central Andes, *Earth Planet. Sci. Lett.*, 134, 9-21.