PALEOMAGNETIC EVIDENCE FOR LATE MIOCENE VERTICAL-AXIS ROTATIONS IN THE PERUVIAN CORDILLERA

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INTRODUCTION

The Andes form the longest non-collisional mountain belt on Earth. They are the widest at the Bolivian Orocline, around 19°S, where a change occurs in the strike direction of the major structures that define the chain. Thirty years of Andean paleomagnetic research has demonstrated a fairly coherent pattern of Cretaceous to Pliocene paleomagnetic rotations that generally vary in concert with the changing structural trends. Counterclockwise rotations are found north of the orocline where structures are northwest oriented, while south of the bend, where the regional fabric strikes north-northeast, rotation sense is mainly clockwise. Uncertainty persists surrounding the origin of this pattern and its link with the deformational history of the chain, especially regarding the length scale and timing of the block rotations. Models proposed to explain this pattern range from wholesale oroclinal bending with large-scale (> 1000 km) rotations and/or differential shortening, to smaller block rotation via local partitioning of strike-slip and thrust-related tectonics (see review in Beck, 1998; Randall, 1998). The obliquity of the Nazca plate convergence direction relative to the South-American margin also likely influences the pattern of the paleomagnetic rotations. The Peruvian Cordillera, which is structurally continuous over a long distance and strikes at a relatively high angle with respect to the convergence direction, provides an excellent setting to study the link between mountain building and paleomagnetism, and eventually discriminate between scale dependant tectonic models. For the Peruvian Andes between 9° and 15°S, Rousse et al (2002) demonstrated that Cretaceous to 9 Ma rocks across the Peruvian Cordillera recorded similar and statistically

significant amounts of rotation (on the order of 15°), and that these rotations took place in a rather brief time at ca. 8 Ma.
To verify the coherence of the paleomagnetic rotations and to better understand their timing and extent, we collected more than 800 cores from widely distributed areas in the Cordillera and the Subandean zone. We report results obtained in the Neogene intracordilleran basins of Cajabamba, San Marcos and the Callejon de Huaylas, as well as in Miocene formations of the Tarapoto region.

PALEOMAGNETIC SAMPLING

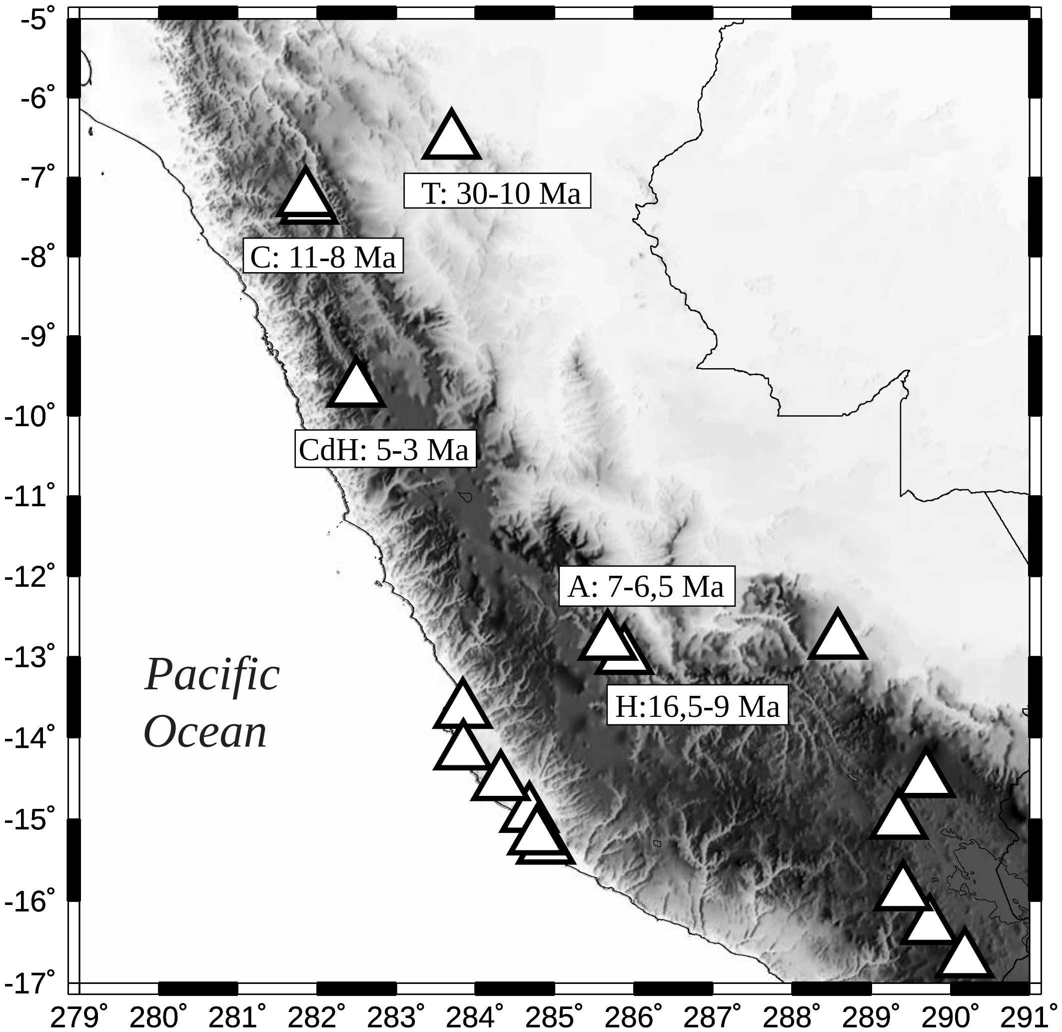

Figure 1: Geographic repartition of the Neogene paleomagnetic sites; A: Ayacucho basin, Ayacucho Formation, C: Cajabamba and San Marcos basins, CdH: Canyon de Huaylas, H: Ayacucho basin, Huanta Formation, T: Tarapoto, Chambira and Ipururo formations. Unlabeled sites were collected in 2001 -results are presently not available.

The subandean zone

In northern Peru, the Subandean zone is a thin-skinned fold and thrust belt which initiated during the Upper Miocene (Audebaud et al., 1973, Nobel and McKee, 1977) and continues today as evinced by high levels of crustal seismicity (Dorbath et al., 1996). In the Tarapoto region (6.6°S, 283.7°E; Fig. 1) we sampled ten sites of Cenozoic sediments from the Chambira (3 sites) and Ipururo (7 sites) formations. The Chambira Formation is constrained in age by palaeontology as Upper Oligocene to Lower Miocene while a Mio-Pliocene age is inferred for the Ipururo Formation by stratigraphic correlation.

The intracordilleran basins

Several Mio-Pliocene basins crop out in the western Cordillera of North and Central Peru. We collected 245 paleomagnetic samples from three of these basins (Cajabamba, San Marcos and Callejon de Huaylas).

The Cajabamba (8 sites) and San Marcos (8 sites) basins lie within the Cajamarca deflection, a major structural feature of northern Peru, characterized by a progressive reorientation of the strike of the fold axes from the NW-directed Andean trend to a more E-W trend. These basins were filled with 1000 to 1300-m-thick fluvial and fluviolacustrine sediments deposited around 11 to 8 Ma (Fourtanier et al., 1993). An extensive paleomagnetic study of the Cajamarca deflection was carried out by Mitouard et al. (1990, 1992) on Cretaceous to Paleogene rocks, who found evidence for significant counterclockwise rotations, on the order of 22°, except for one isolated region which was not significantly rotated. They concluded that the age of the rotations post-dated the Late Eocene.

The Callejon de Huaylas basin lies west of the Cordillera Blanca batholith, which today forms the highest peaks of the Peruvian Andes. The batholith was emplaced at 8.2±0.2 Ma (concordant U-Pb zircon age; McNulty et al., 1998). The basin's southern part is filled with the 2000 m-thick Lloclla Formation, from which we sampled two sections. Three K-Ar whole rock ages of 5.4±0.1 and 4.65±0.1 Ma were obtained from a tuffaceous horizon at the base of the Lloclla Formation (Bonnot, 1984).

RESULTS AND DISCUSSION

A combined mean direction was calculated for the Chambira and Ipururo formations from the subandean zone. The fold and reversals tests are positive, suggesting a primary origin of the remanence. Relative to the 20 Ma reference pole from Besse and Courtillot (2001), no significant rotation or flattening is recorded. The pole we obtained is also concordant with the Neogene 5 to 24 Ma reference pole from Randall (1998) and lies close to the only Late Miocene pole available for South America (Remedios formation, Brazil, Shultz et al., 1986). The Tarapoto pole can thus be considered as a South American reference pole for the time period ~ 28 to 7 Ma. It probably defines the eastern limit of the Miocene anticlockwise rotations. For the intracordilleran basins, thermal and alternating field demagnetization isolate stable magnetic components which pass fold and reversals tests. Site mean directions show rotations ranging between -21° and +6°. Interestingly, when rotations were found in Cretaceous rocks (Mitouard et al., 1992), the same amount of rotation was registered in nearby Miocene rocks. Moreover, in one case, when Cretaceous rocks recorded no rotation, none was observed either in Miocene rocks. This suggests that, despite several episodes of deformation between the Cretaceous to Present, only the latest one has provoked vertical axis block rotations. These results corroborate with our previous work in the Ayacucho basin (Rousse et al., 2002), and confirm the Neogene origin of the paleomagnetic rotations in the Peruvian Cordillera.

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