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Paleomagnetism of the Miocene Jantetelco Granodiorites and Tepexco Volcanic Group and inferences for crustal block rotations in central Mexico — Reevaluation

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ABSTRACT

Miocene igneous rocks from a location in central Mexico provide paleomagnetic data that allow re-evaluation of previous data by Urrutia-Fucugauchi (1981) that were interpreted to suggest a counter clockwise rotation of a crustal block by about 50°. We sampled 31 sites from the Miocene trondhjemitic Chalcatzingo domes, the Tepexco volcanic group, and the Xalostoc diorite, covering the same area of approximately 50 km^2 about 90 km SE of Mexico City. Magnetic analysis shows that these rocks contain magnetic phases of variable composition, with Curie temperatures characteristic for magnetite, but often accompanied by lower Curie temperature components. Magnetic hysteresis measurements point to the presence of PSD particles, and in combination these properties suggest that these rocks are also suitable for paleomagnetic study. Scanning electron microscope analysis supports the rock magnetic results, indicating the presence of magnetite and high-intermediate titanium titanomagnetite in many samples. Demagnetization experiments showed in most cases characteristic remanence directions of reasonable to good quality, and for 26 sites mean directions could be determined. Of these 14 (12) are of normal (reverse) polarity. Overall mean directions of normal and reverse sites are antipodal and pass a reversal test at the 95% probability level. The paleodirection from 26 sites is D = 348.1°E, I = 35.7°, α_{95} = 7.4°, and the paleopole is located at Lat = 78.3°N, Long = 184.2°E, A_{95} = 7.0°, which is indistinguishable from the 20 Ma reference pole for the stable North America plate. These data do not support any tectonic deformation of the sampling area since the Miocene. Based on the number of sites studied, their rock magnetic characteristics, and the quality of the magnetic remanence that results in a positive reversal test, we consider our data to be reliable and we therefore suggest that this result supersedes that of Urrutia-Fucugauchi (1981). The reason for this previous and much different result remains unknown.

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1. Introduction

Paleomagnetism uses the earth's magnetic field recorded in rocks as a marker for kinematic analysis of movements in the crust. It has been successfully applied for reconstructing tectonic processes on very different scales. One of the first applications was to test the hypothesis of continental drift, by comparing paleopoles from different tectonic plates (e.g., Collinson and Runcorn, 1960; Creer et al., 1959; Irving and Green, 1958; Runcorn, 1956). On a smaller scale, the displacement of tectonostratigraphic terranes has been studied and it has been suggested that they have traveled over long distances until their amalgamation to another tectonic plate, e.g., for the western North America Cordillera (e.g., Beck, 1980; Irving et al., 1996). Finally, neotectonic processes in active lateral fault systems have been quantified in terms of their extent and temporal evolution using paleomagnetic data to determine crustal block rotations, e.g., in California (Luyendyk et al., 1980) or the Aegean (Kissel and Laj, 1988).

Mexico today belongs to the North America plate, but most of southern Mexico is believed to be a mosaic of allochtonous terranes that were accreted in the past. Baja California is an example for such accretion processes: while it was part of the North America plate before about 12 Ma ago, it later separated by the introduction of the East Pacific Spreading center and the opening of the Gulf of California and accreted to the Pacific plate. Today it moves roughly northward with respect to the North America Plate. Southern Mexico is composed of several terranes that have moved into their present position after breakup of Pangea (e.g., Sedlock et al., 1993) (Fig. 1). Paleomagnetic studies resulting in divergent paleopoles have not only provided evidence for such movements previous to the Cretaceous (e.g., Ballard et al., 1989;

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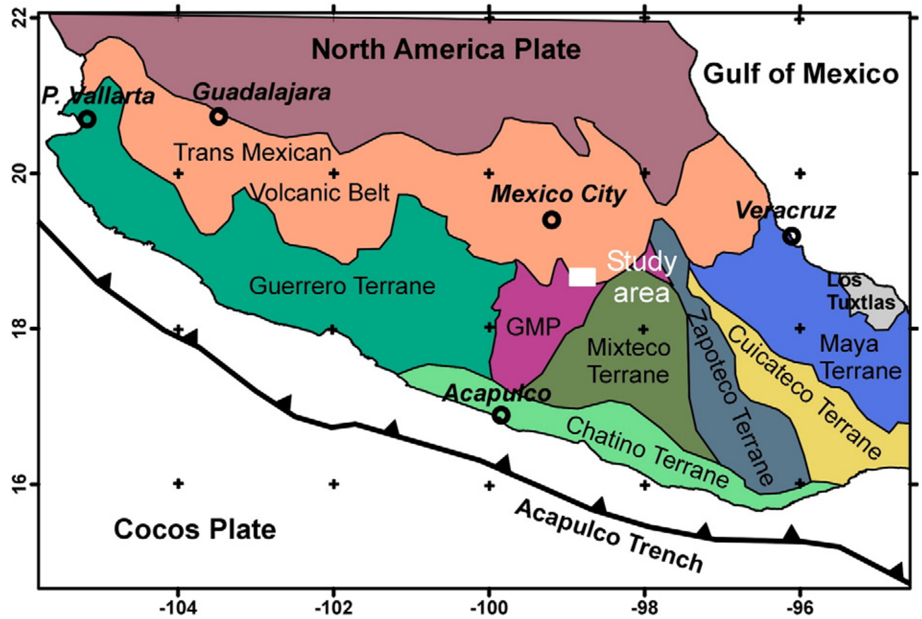

Fig. 1. Terrane map of southern Mexico and the Trans Mexican Volcanic Belt (modified after Ortega-Gutiérrez et al., 2012). GMP, Guerrero-Morelos platform. Major cities are shown with black circles for reference. The study area is marked by a white rectangle.

Böhnel, 1989; Godínez-Urban et al., 2011), but also shown that most of Mexico had acquired its present day configuration probably since the mid-Cretaceous (Böhnel et al., 1989, 2002; Molina-Garza et al., 2014).

The Transmexican Volcanic Belt (TMVB) is a subduction related volcanic arc that has evolved since about 15 Ma (e.g., Aguirre-Díaz et al., 1997; Ferrari et al., 1999). It is situated between several tectonostratigraphic terranes (Fig. 1), and while these are of much older age, these terranes may have influences the origin and orientation of the belt. With respect to other volcanic arcs, the TMVB forms an angle of ~20° with respect to the subduction trench. Three main hypotheses to explain this anomaly are: 1. Variable subduction angle along the trench, decreasing from ~50° in the NW to subhorizontal in the SE (Pardo and Suarez, 1995). This shallowing subduction of the angle would result in a depth of magma fusion that becomes more distant to the subduction trench to the SE. 2. The presence of old suture zones between terranes along the track of the TMVB that facilitate the up rise of magma (e.g., Molnar and Sykes, 1969; Mooser, 1972). 3. A transtensional shear system in response to differences in plate velocities of the North America, Pacific and Caribbean plates (Shurbet and Cebull, 1984). Such a shear system is also considered to be viable in view of the neotectonic activity along the TMVB, as shown by structural geology data and by historic earthquakes that have occurred within the upper crust (e.g., Suter et al., 1995, 2001).

Early paleomagnetic results seemed to support the presence of a left lateral shear system beneath the TMVB (Urrutia-Fucugauchi, 1981; Urrutia-Fucugauchi and Böhnel, 1987, 1988). Paleomagnetic mean directions from 10 rock units of Cretaceous to Quaternary age distributed along the TMVB showed in most cases counter clockwise rotated declinations, but only rarely a significant inclination difference. The data were thus interpreted as indicators of localized crustal block rotations around vertical axes within a left lateral shear system (Urrutia-Fucugauchi and Böhnel, 1987, 1988). Notably, later paleomagnetic studies from the TMVB have rarely encountered similar counter clockwise rotations (e.g., reviews by Mejia et al., 2005; Ruiz et al., 2010), so that the validity of these early paleomagnetic studies may be in doubt. We present a re-evaluation of the first study which proposed such a counter clockwise rotation of a crustal block in central Mexico, by ~50° (Urrutia-Fucugauchi, 1981). This work is based on the thesis results of Vazquez Duarte (2010) and complementary data obtained before and afterwards.

2. Geology of the study area and paleomagnetic sampling

The study area is located southeast of Mexico City, along the central part of the TMVB (Fig. 1). The geology has been studied by Fries (1966) and is resumed by Rivera et al. (1998) in the 1:250,000 geologica map published by the Servicio Geológico Mexicano. More recent results by Gómez-Tuena et al. (2008) and Ortega-Gutiérrez et al. (2012) report the geochemistry and petrology of the Chalcatzingo domes (previously known as Jantetelco granodiorites) and the xenoliths contained in them.

In the study area, the local basement is not exposed but overlain by the Cretaceous Guerrero-Morelos platform (GMP) (Fig. 1), mainly formed by platform-facies carbonate rocks. Located to the west of the GMP is the Jurassic to Cretaceous Guerrero terrane, and to the east the Paleozoic Mixteco terrane, and the basement in the study area could thus correspond to either of these. Based on the analysis of numerous xenoliths occurring in the Chalcatzingo dome, Ortega-Gutiérrez et al. (2012) suggest that the local basement is of Proterozoic age, which excludes the Guerrero and rather favors the Mixteco terrane. The GMP is unconformably overlain by the Eocene Balsas Formation, a sequence of continental conglomerates and red bed sedimentary rocks, which in turn is covered by Oligocene to Miocene volcanic rocks of the Buenavista-Tepoztlan and the Tilzapotla (named by Fries (1966) in eastern part of our study area Tepexco volcanic group) Formations. These rocks are covered by widespread upper Pliocene lahars of the Cuernavaca Formation and alluvial sediments. Intrusive rocks like the Xalostoc diorite are of similar age as the Chalcatzingo domes (Fries, 1966).

Several tectonic processes have affected the study area, with the oldest events of pre-Cenozoic age. These will not be discussed here, as they could not have affected the Miocene igneous rocks we have studied. During the Cenozoic and Quaternary, three tectonic events are important. The oldest and most important event is the Laramide orogeny, which took place between 80 and 40 Ma and was related to increased convergence between the Pacific and North America plates (e.g., Engebretson et al., 1985). This resulted in the Sierra Madre Occidental fold belt and important compressional tectonic features in the Sierra Madre del Sur (Cerca et al., 2007) and thus possibly led to the folding observed in the rocks of the MGP. This deformation pre-dates the emplacement of the Miocene rocks in the study areas.

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