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Volcán Tancítaro, Michoacán, Mexico, $^{40}Ar/^{39}Ar$ constraints on its history of sector collapse

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Abstract

Volcán Tancítaro is a 97±3 km^3 stratovolcano located in the Michoacán Guanajuato volcanic field (MGVF), part of the Trans Mexican Volcanic Belt. Prior to this study, there was only one K–Ar date (530±60 ka; [Ban, M., Hasenaka, T., Delgado-Granados, H., Takaoka, N., 1992. K–Ar ages of lavas from shield volcanoes in the Michoacán–Guanajuato volcanic field, Mexico. Geofisica Internacional 31 (4), 467–473.] and one sector-collapse event reported for this volcano in the literature [Garduño-Monroy V.H., Corona-Chavéz, P., Israde-Alcantara, I., Mennella, L., Arreygue, E., Bigioggero, B., Chiesa, S., 1999. Carta Geológica de Michoacán, scale 1:250,000. Universidad Michoacana de San Nicolás de Hidalgo.; Capra, L., Macías, J.L., Scott, K.M., Abrams, M., Garduño-Monroy, V.H., 2002. Debris avalanches and debris flows transformed from collapses in the Trans-Mexican Volcanic Belt, Mexico — Behavior, and implications for hazard assessment. Journal of Volcanology and Geothermal Research 113, 81–110.]. Twenty-six new $^{40}Ar/^{39}Ar$ ages indicate that Volcán Tancítaro became active ≥793±22 ka and that the most recent effusive activity occurred at 237±34 ka. Two catastrophic sector-collapse events are identified and dated; the first one occurred on the west side between 694 and 571 ka, whereas the second one occurred on the east side between 261 and 238 ka. The older collapse produced a 2.3–3.4 km^3 debris-avalanche and laharic deposit spread over ~567 km^2, whereas the more recent collapse left a 3-km wide, horseshoe-shaped scar on the eastern flank and produced a 3.6–7.0 km^3 debris-avalanche and laharic deposit that covers ~654 km^2. Reconstruction of the main edifice of Volcán Tancítaro using ArcGIS software and digital elevation models indicates that the volume removed during the eastern sector collapse was ~4.7 km^3.

Keywords: volcanic hazards; debris avalanche; lahar; GIS; composite volcano; volcano reconstruction

1. Introduction

Volcán Tancítaro is a large (~100 km^3) andesitic, composite volcano located in the Michoacán–Guanajuato Volcanic Field (MGVF) in west-central Mexico (Fig. 1). With a height of 3840 m, rising >2000 m above the surrounding landscape, V. Tancítaro is the dominant feature in the MGVF. In addition to its size and height, the structural setting of V. Tancítaro in a tectonically active region (Connor, 1987; Pacheco et al., 1999) has contributed to its gravitational instability, leading to sector collapses, which have produced debris avalanches and related lahars in its geologic history. This is evidenced by a 3-km wide, horseshoe-shaped scar on its east side (Fig. 2), the presence of debris-avalanche deposits on both the western and southeastern slopes of the volcano, and a wide fan of related laharic deposits on which the surrounding

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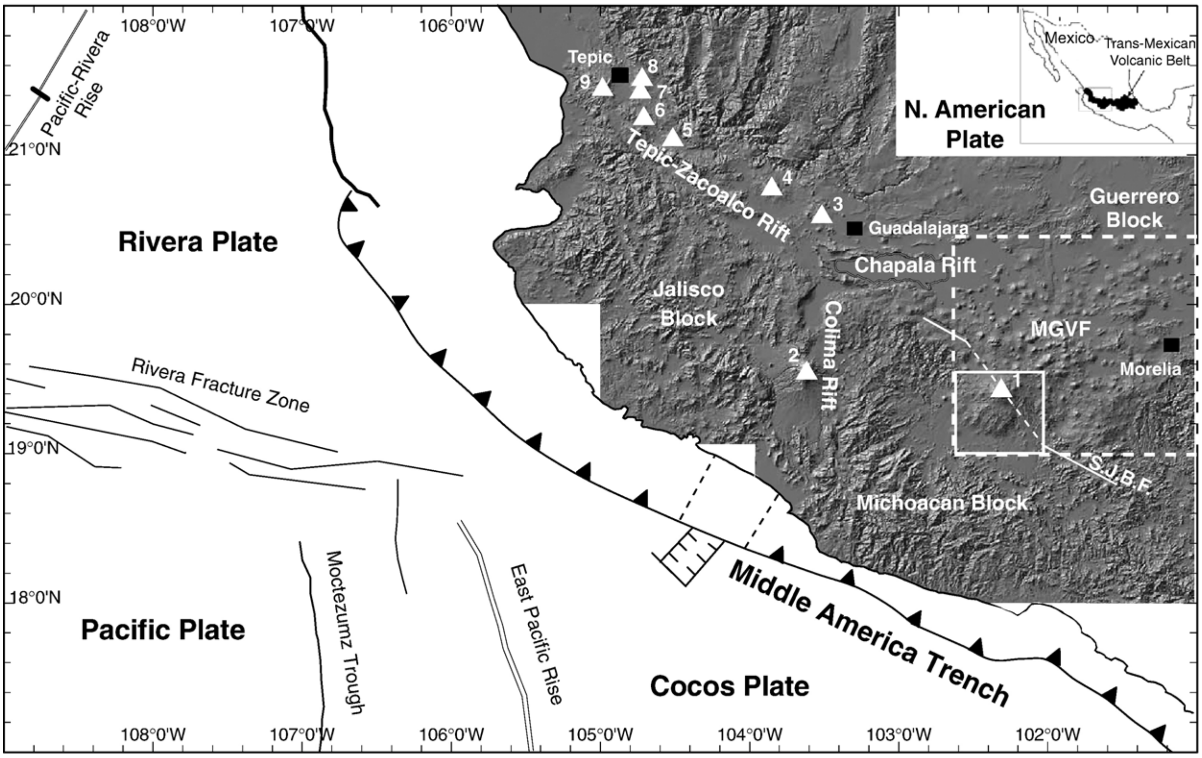

Fig. 1. Tectonic overview of western Mexico, modified from Delgado–Granados (1993). Numbered triangles refer to volcanic centers: (1) V. Tancítaro, (2) V. Colima, (3) Sierra La Primavera, (4) V. Tequila, (5) V. Ceboruco, (6) V. Tepetiltic, (7) V. Sangangüey, (8) V. Las Navajas, (9) V. San Juan. S.J.B.F. = San Juanico–Bueanavista Fault. The dashed box represents the Michoacán Guanajuato Volcanic Field (MGVF).

communities of Buenavista Tomatlán, Apatzingán, and Nueva Italia reside (Garduño-Monroy et al., 1999; Capra et al., 2002).

Large composite volcanoes like V. Tancítaro have complex histories of growth and collapse, which require detailed geochronology and mapping to fully understand. Stratovolcanoes are built through the accumulation of lava and pyroclastic eruptions, which can be dated by a variety of methods; the most common is ^{40}Ar/^{36}Ar geochronology. However, sector-collapse events are difficult to date because juvenile (magmatic) material may be absent or difficult to find within them. In several cases, the associated debris-avalanche deposits are dated by the radiocarbon method applied to organic material entrained during the event (e.g. Brantley and Glicken, 1986; Siebe et al., 1992; Wright, 1998; Belousov et al., 1999; Thouret et al., 2001); however, this approach cannot be applied to deposits that date back several hundred thousand years.

An alternative approach is to apply ^{40}Ar/^{39}Ar geochronology to the numerous cinder cones, lava flows, and shield volcanoes that surround V. Tancítaro; these are found both above and below the debris deposits. In recent years, the ^{40}Ar/^{39}Ar method has been shown to reliably date lavas <1 Ma (e.g. Hildreth and Lanphere, 1994; Renne et al., 1997; Singer et al., 1997; Frey et al., 2004; Lewis-Kenedi et al., 2005; Jicha and Singer, 2006). Therefore, one goal of this study is to use ^{40}Ar/^{39}Ar geochronology to bracket the age of two debris-avalanche deposits derived from sector-collapse events at V. Tancítaro.

A second goal of this paper is to use digital elevation models and Geographic Information Systems (GIS) software to estimate the volume of material involved in the collapse events at V. Tancítaro. The volume of material involved during a sector collapse is one of the most important factors in determining the energy released and the travel distances of the associated debris avalanches and lahars (Iverson, 1997; Iverson et al., 1998). For events <0.1 km^3, flume experiments can be conducted where both the volume of material and the area inundated by a debris flow are well constrained. However, for collapse events at stratovolcanoes involving >1 km^3 of material, researchers must rely on the few well-mapped historical occurrences. The advent of digital elevation models and GIS software allows the study of prehistoric debris-avalanche deposits and an estimate of their volumes, which can be added to the