Sedimentology, Stratigraphy and Palynology of the Volcaniclastic Tepoztlán Formation (Lower Miocene, Central Mexico): Implications for the Evolution of the Transmexican Volcanic Belt

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Nubes - incertum procul intuentibus ex quo monte; Vesuvium fuisse postea cognitum est - oriebatur, cuius similitudinem et formam, non alia magis arbour, quam pinus expresserit. Nam longissimo velut trunco elata in altum, quibusdam ramis diffundebatur, credo quia recenti spiritu evecta, dein senescente eo destituta, aut etiam pondere suo victa, in latitudinem evanescebat, candida interdum, interdum sordida et maculosa, prout terram cineremve sustulerat.

A cloud arose - whoever saw it from afar, did not know, from which mountain; that it came from the Vesuv was only recognized later – whose appearance reminded of no other tree than the pine. The cloud rose up as an excessive trunk, lofty and ramified into many branches; I believe that it, lifted up by arising wind, then lost its strength due to waning wind or weighted by its own weight and spread out, occasionally white, occasionally dirty and spotted after having carried soil and ashes.

C. Plinius Secundus ep. 6.16
Pliny the Younger in his letter to Tacitus after the eruption of Vesuvius in 79 A.D.
- the first description of a volcanic eruption in human history.

Abstract

Volcaniclastic depositional series give insights into the interaction of evolving volcanic edifices and their ejecta with co-existing drainage systems. These are often the only remnants of continental magmatic arcs. The Tepoztlán Formation represents a remnant continental arc succession, representing the initial phase of the Transmexican Volcanic Belt (TMVB). The sedimentology of the Tepoztlán Formation records volcaniclastic resedimentation in alluvial and fluvial settings related to erosion and remobilization of huge volumes of ignimbrites and lava following explosive and effusive eruptions during the Lower Miocene. Rapid facies changes and the lack of regional stratigraphic markers indicate that the volcanic rocks of the Tepoztlán Formation erupted from a number of vents, many of which are marked by domes, lava flows and close-to-vent facies. For the first time, a genetic model explaining the evolution of the Tepoztlán Formation is presented. The volcaniclastics accumulated in volcanic flank and apron settings mainly in proximal to medial distances to their source area. Initially, pyroclastic material was mostly reworked by sheet floods and fluvial processes, indicating that volcanic centers were small and possibly more distant to the main depositional area. Increased production of volcanic material and growth of the young TMVB led to a progradation of the volcanic depositional system, characterised by coarsening-upward and increasing occurrence of coarse conglomerates, which temporarily overloaded and buried the fluvial system with debris. Thick pyroclastic flows spread over the area which still had a smooth topography. Continuous build-up of the volcanic centers, however, accentuated the topography, and mass flow deposits became more and more the dominant depositional process with intense mixing and reworking of primary volcanic products.

By means of K-Ar and Ar-Ar geochronology, eight magnetostratigraphic sections, and lithological correlations, a chronostratigraphy for the entire Tepoztlán Formation was constructed. Correlation of the resulting 577 m composite magnetostratigraphic section with the Geomagnetic Polarity Time Scale (GPTS) of Cande and Kent (1995) suggests that this section spans from 22.8-18.8 Ma (6Bn.1n-5Er; Aquitanian-Burdigalian, Lower Miocene). This correlation implies a deposition of the Tepoztlán Formation predating the extensive effusive activity in the TMVB at 12 Ma and is therefore interpreted to represent its initial phase with predominantly explosive activity. Additionally, a new subdivision of the Tepoztlán Formation into three units was established according to the dominant mode of deposition: (1) the fluvial dominated Malinalco Member (22.8 – 22.2 Ma), (2) the volcanic dominated San Andrés Member (22.2 – 21.3 Ma) and (3) the mass-flow dominated Tepozteco Member (21.3 – 18.8 Ma).

For palynological analyses fine-grained fluvial deposits, the matrix of lahar deposits and deposits from pyroclastic density currents were investigated for the first quantitative palaeoclimate reconstruction of the Early Miocene in Central Mexico. The samples yield a diverse pollen and spore assemblage, enabling a palaeoenvironmental and climatological interpretation of the Tepoztlán Formation. A palynomorphal assemblage of 38 angiosperm, seven gymnosperm and eight pteridophyte/ bryophyte taxa was identified. The taxa group into two palaeocommunities, riparian and deciduous forest, respectively, representing several stages of the recolonization of plants on disturbed ground after initial volcanic eruptions. For climate reconstruction the coexistence approach was applied to the palynomorphs of the Tepoztlán Formation. The mean annual temperature (MAT) was about 14.5°C (present MAT 20°C), and mean annual rainfall around 1200 mm (present 770 mm). The Lower Miocene (Upper Aquitanian – Lower Burdigalian) was a period of cool temperate and humid climate in this area pointing to an already highly elevated plateau with volcanic edifices clearly exceeding 3000 m in altitude. Furthermore, the data show that the seasonality was stronger compared to the modern climate as documented by colder winters and warmer summers which was due to the open Central American Seaway enhancing monsoonal transport of air masses in Mexico during the Lower Miocene.

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