Palaeoenvironmental Reconstruction of the Miocene Tepoztlán Formation (Central Mexico): Preliminary Results of Palynological Investigations

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Introduction

In Miocene times, a major volcano-tectonic change took place due to a re-organization of the tectonic plates in the western Pacific region. Since the Mid-Miocene, the Transmexican Volcanic Belt (TMVB, Fig. 1) began to form (Delgado-Granados et al. 2000). However, there is still a controversial scientific debate on its development. The aim of our study is to establish a stratigraphic framework and a palaeoenvironmental interpretation of the Mid-Miocene Tepoztlán Formation.

To date, palaeobotany in volcanic settings has dealt with intercalated sediments namely paleosoils, fluvial volcaniclastic sandstones, peat or lignites (e.g., Lund 1988, Hilton et al. 2004). Even authors working on tuffaceous material focussed on either the macroflora (e.g., Pole 1994) or charcoals (Scott and Glasspool, in press). Publications on palynology in pyroclastic rocks and their reworked deposits (lahars and fluvial deposits) are rare (Satchel 1982, Taggert & Cross 1990, Jolley 1997, Bell & Jolley 1997). In this study we investigated a volcaniclastic section of the Mid-Miocene Tepoztlán Formation with respect to palaeoenvironment using palynology. This method has not been applied to this formation previously.

Geological setting

The study area is situated along the southern edge of the TMVB in the state of Morelos, where Tertiary volcaniclastic series emerge underneath Quaternary volcanics (Fig.1). In spite of the spectacular outcrops of these up to 800 m thick volcaniclastic successions around the towns of Malinalco, Tepoztlán and Tlayacapan, the so called Tepoztlán Formation belongs to the least studied rocks of the TMVB. The Tepoztlán Formation is underlain by the Balsas Formation, a terrestrial-lacustrine sedimentary succession also rich in volcaniclastics. It is probably representing the earliest volcanic phase of the region (Fig. 2).

The Tepoztlán Formation consists of a characteristic succession of lahars (debris-flow and hyperconcentrated-flow deposits), pyroclastic-flows, occasional andesitic to dacitic lavaflows and intercalated fluvial or lacustrine sediments, attaining thicknesses of several hundred meters. K/Ar geochronology on a dacitic lava flow in the lower part of the Tepoztlán Formation and a younger dike reveals an age of the formation of between 21.85 ± 0.21 Ma and 15.83 ± 1.31 Ma. Thus, a deposition between Early to Mid-Miocene is proposed (Lenhardt et al. 2006).

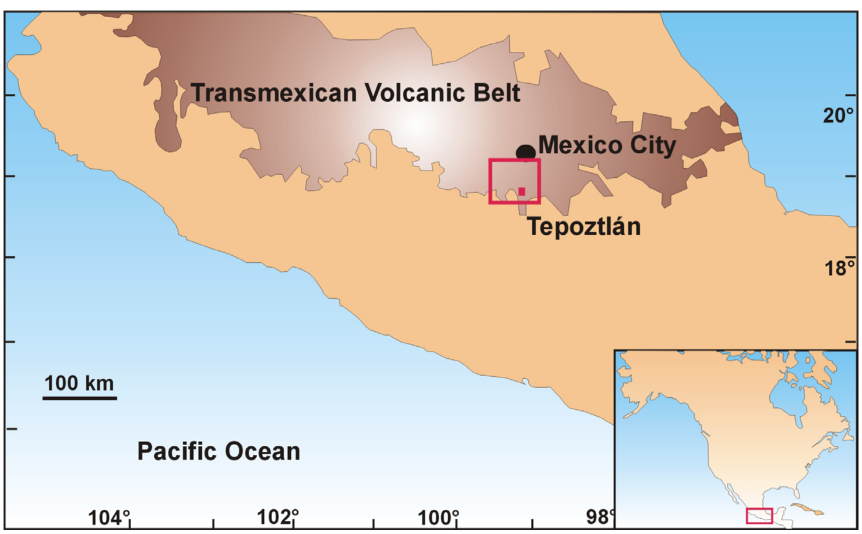

Figure 1. Extend of the Transmexican Volcanic Belt in Central Mexico. The position of the study area is indicated.

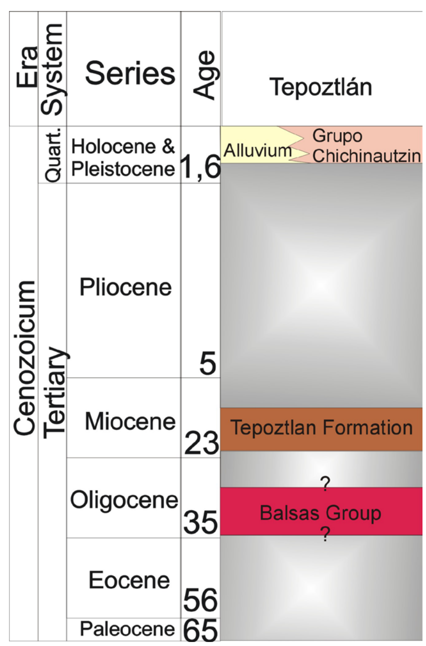

Figure 2. Stratigraphic succession in the study area.

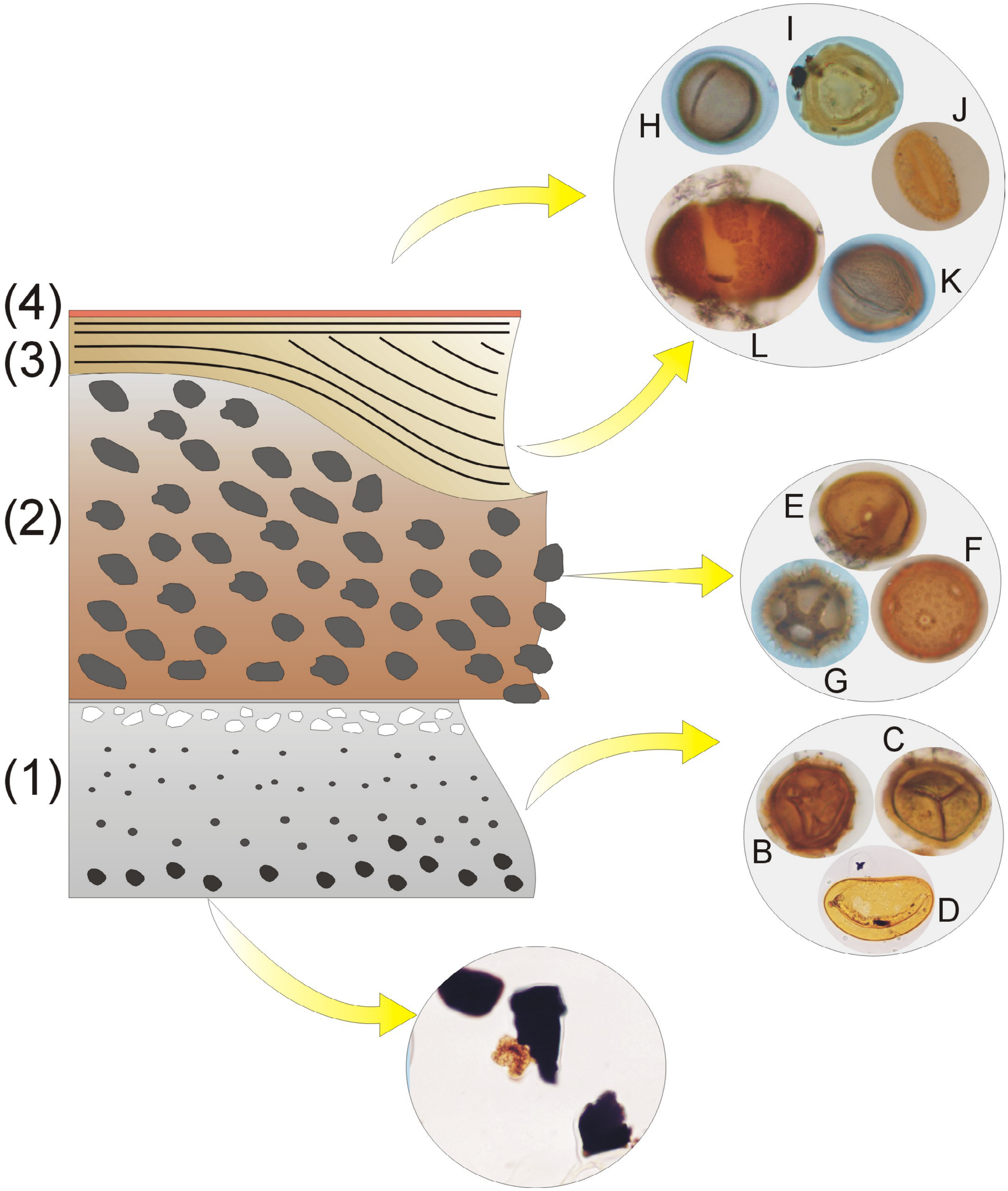

Figure 3. Ideal sedimentary succession of volcaniclastic sediments and characteristic sedimentary organic particles: (1) pyroclastic flow deposit, (2) lahar, (3) fluvial deposit, (4) lacustrine or waning-flood deposit.
A charcoal, B *Lycopodium* sp. (51 µm), C *Selaginella* sp. (42 µm), D Polypodiaceae (45 µm), E Graminae (38 µm), F Compositae (16 µm), G Caryophyllaceae (17 µm), H *Quercus* sp. (18 µm), I *Betula* sp. (22 µm), J *Salix* sp. (18 µm), K *Acer* sp. (20 µm), L *Pinus* sp. (61 µm).

Materials and methods

For palynological analyses we investigated samples of 150 g each representing the fine-grained matrix of fluvially reworked deposits, lahars, ash-flow deposits, and clayey layers on top of these deposits.

All samples were processed following the standard palynological processing techniques, which include the treatment with HCl (30%), HF (73%) and heavy liquid separation with $ZnCl_2$ solution. All samples were centrifuged and washed with distilled water after each step. The residue was cleaned by sieving using an 11 μm mesh. For strew mounts we used Eukitt, a commercial mounting medium on the base of resin. The counting is based on 50 pollen grains and spores per slide. All samples reveal a well preserved and diverse pollen and spore assemblage, enabling a preliminary palaeoenvironmental interpretation of the Tepoztlán Formation.

Preliminary palaeoenvironmental reconstruction

As far as we can conclude from first analyses, the pyroclastic and volcaniclastic sediments show characteristic stratigraphical vegetation patterns (Fig. 3). The base of pyroclastic-flow deposits is marked by a high amount of charcoal particles (unit 1 in Fig. 3), wood material that was burned due to the heat during a volcanic eruption, whereas the top is rich in fern spores, the first colonizers after an eruption (Spicer et al. 1985). This points to the development of thin palaeosoil layers although a sedimentary record is lacking.

The lahars (unit 2 in Fig. 3), representing reworked deposits that were formed within days to tens of years after the initial eruption, show the development of the first higher plant communities. These are dominated by the plant families Graminae, Compositae and Caryophyllaceae. Finally, fluvial and lacustrine sediments (units 3 and 4 in Fig. 3) show the tree population of a mature mixed forest that is dominated by oaks and pines.

The above described stratigraphic vegetation patterns are interpreted in terms of short-term destruction-recolonization cycles that are controlled by eruptions and intermittent quiescence (Fig. 4). After an initial eruption (Fig. 4a), the volcanic deposit is settled quickly by ferns and other opportunists, colonizing open and disturbed ground (Collinson 1996). The aftermath of the eruption is characterized by the deposition of lahars (Fig. 4b). The second stage of re-colonization involves herbaceous plants, mostly Compositae, and grass as the first higher evolved pioneer plants, followed by pines as the first trees. Later a mature mixed forest develops (Fig. 4c and 4d). Modern botanic studies on the Canary Islands (Dale et al. 2005) show that the pioneer phases on volcanic ash take about 20 to 30 years, trees appear first after 200 to 300 years. As a modern analogue of the Tepoztlán Formation, Fig. 5 shows volcaniclastic deposits of the eruption of the Cotopaxi volcano (Ecuador) in 1877 with four sedimentation phases recognized. After the initial deposition of pyroclastic flows (Fig. 5a), the following years were characterized by debris flows (Fig. 5b) caused by rain storms. After tens of years, the lack of further sediment supply caused the change from debris flows to fluvial deposition (Fig. 5c, d). Today´s development of the vegetation of this area (130 years after the eruption) is characterized by the transition from grass- and scrub-land to the appearance of the first trees.

Present day vegetation of Central Europe is very similar to that recorded in the Tepoztlán section. Thus, the depositional environment of the Tepoztlán Formation displayed a rather temperate climate. These palaeoclimatic signatures, indicating moderate temperatures in Miocene low latitudes may be caused by a high palaeoaltitude. This in turn may point to an early uplift of Central Mexico. Further studies and statistical methods based on modern analogues have to clarify this hypothesis.

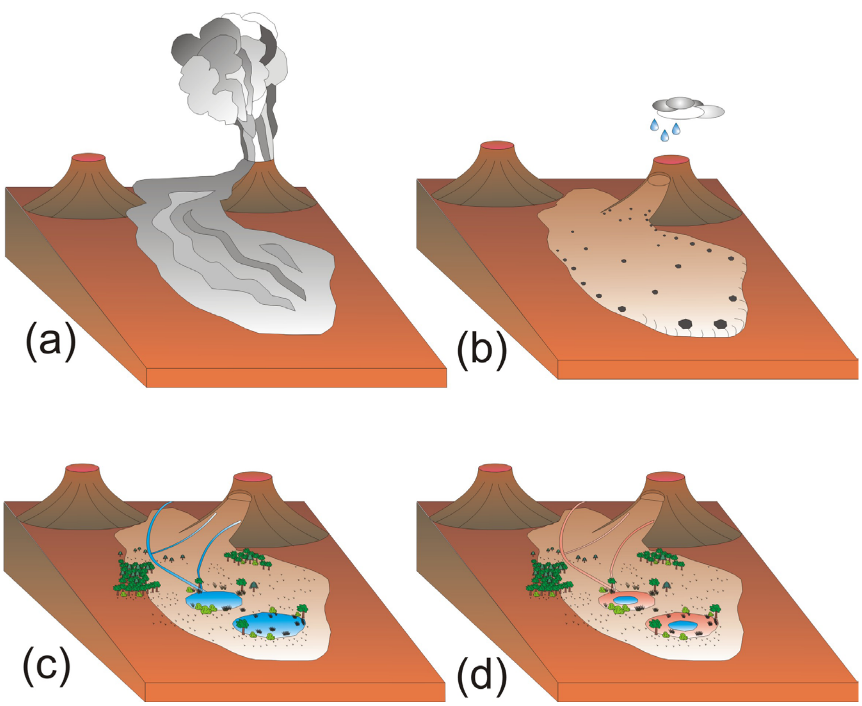

Figure 4. Changes in palaeoenvironment within time: a) ash flow, b) debris flow (lahar), c) fluvial reworking, d) waning stage.

Acknowledgements

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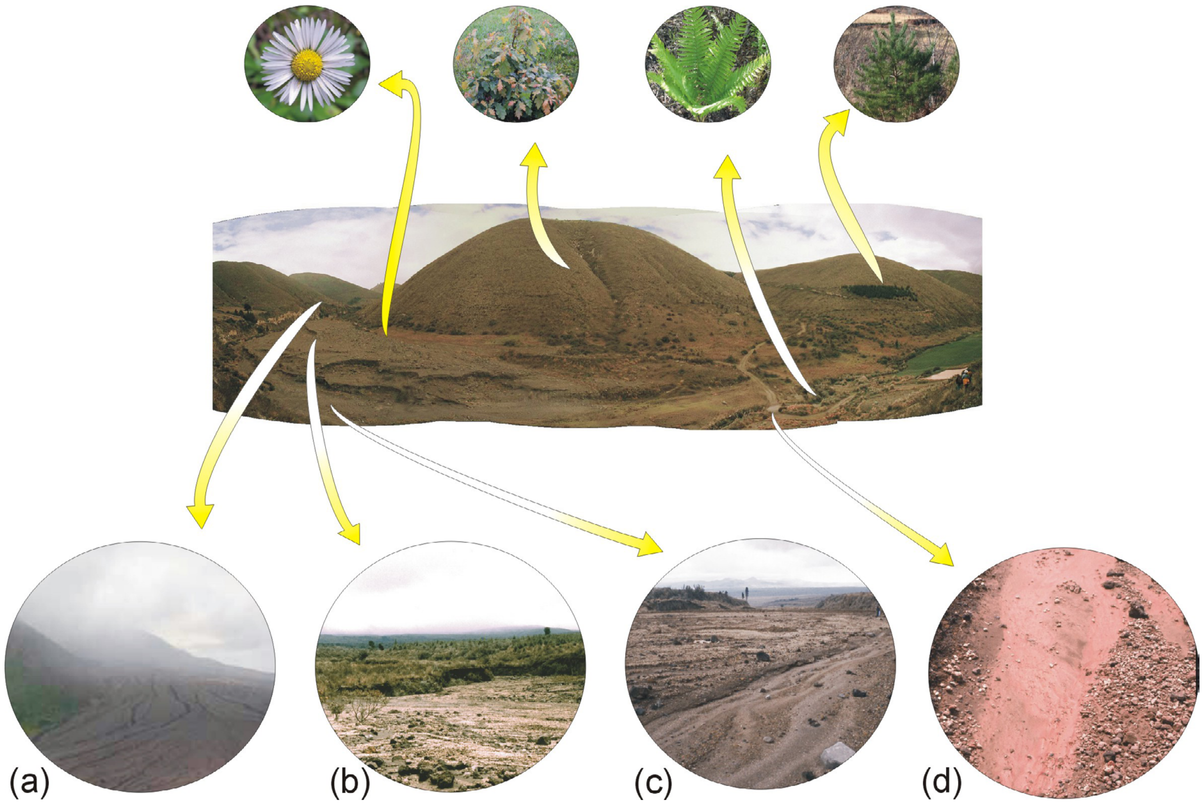

Figure 5. Modern analogue of the Tepoztlán Fm. (here with volcaniclastic deposits and their vegetation from the recent eruption of Cotopaxi, Ecuador, in 1877): a) pyroclastic-flow deposit, b) lahar, c) fluvial reworked deposits, d) waning-flood deposits.

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