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The ~23,500 y ^{14}C BP White Pumice Plinian eruption and associated debris avalanche and Tochimilco lava flow of Popocatépetl volcano, México

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ABSTRACT

The White Pumice (WP) is one of the thickest and most voluminous Plinian fallouts produced by Popocatépetl volcano in central Mexico during the Late Pleistocene-Holocene. Its eruption ~23,500 ^{14}C y BP (27,800 cal BP) was triggered by the catastrophic failure of the SW flank of the volcano. The resulting debris avalanche was highly mobile reaching 72 km from the cone with an apparent coefficient of friction (L/H) of 0.06. The deposit covers an area of ~1200 km^2, and has a volume of 10.4 km^3. This gigantic landslide, characterized by exceptionally large proximal hummocks (>400 m) provoked the sudden decompression of the hydrothermal and magmatic systems, which produced an initial blast followed by the rise of a Plinian column that reached an altitude of ~33 km. The isopach map allows the recognition of a dispersal axis pointing toward the south, where an area of ~2490 km^2 was covered by >10 cm of pumice and ash. The total volume of the pumice fallout was estimated at ~1.9 km^3 DRE (Dense Rock Equivalent). Pumice clasts are dacitic (62–66 wt.% SiO_2, anhydrous basis), highly vesicular (55–88 vol.%) and display a seriate texture with phenocrysts of plagioclase + hornblende + augite + hypersthene + oxides (Ti-magnetite and ilmenite) + apatite.

As the eruption advanced, discharge rates became more intermittent and the height of the column fluctuated and finally collapsed, generating pumice-and-ash flows that were emplaced around the volcano. This short but intense activity was followed during subsequent years by rain-induced lahars that reached great distances from the volcano. At the same time, more degassed andesitic-dacitic (61–65 wt.% SiO_2) magma was erupted effusively (4.4 km^3, DRE) in the new horseshoe-shaped ~5 km-wide crater from which the Tochimilco lava flow descended toward the SSE, where it inundated an area of ~68 km^2 and reached as far as ~22 km from its source. Since then, multiple eruptions have reconstructed the summit cone, almost completely obliterating the horseshoe-shaped crater.

During the course of this catastrophic eruption (VEI = 5) a total volume of ~6.3 km^3 (DRE) of juvenile magma (pumice and lava) were emitted and at least an additional ~10 km^3 of pre-existing rocks (debris avalanche) mobilized. It surpasses in magnitude most other known Plinian eruptions from Popocatépetl and can be envisaged as an example of a worst-case scenario for hazard evaluation purposes. It dramatically changed the morphology of the volcano and had profound and far-reaching effects beyond its immediate vicinity along rivers draining surrounding plains as well as on the lacustrine basins (e.g. Chalco) to the NE. A repeat of such an eruption in this densely populated area would certainly cause a major calamity of unprecedented dimensions.

1. Introduction

Popocatépetl (5452 m a.s.l.) is an andesitic-dacitic strato-volcano located in the central part of the Trans-Mexican Volcanic Belt (TMVB), a magmatic arc related to the subduction of the oceanic Cocos Plate underneath the continental North America Plate (Schaaf et al., 2005). More precisely, it is at the southern end of the Sierra Nevada, a north-south trending volcanic range that separates the Basin of Mexico City in the west from the valley of Puebla in the east (Fig. 1). After decades of dormancy, Popocatépetl became reactivated in December 1994 threatening nearby populations

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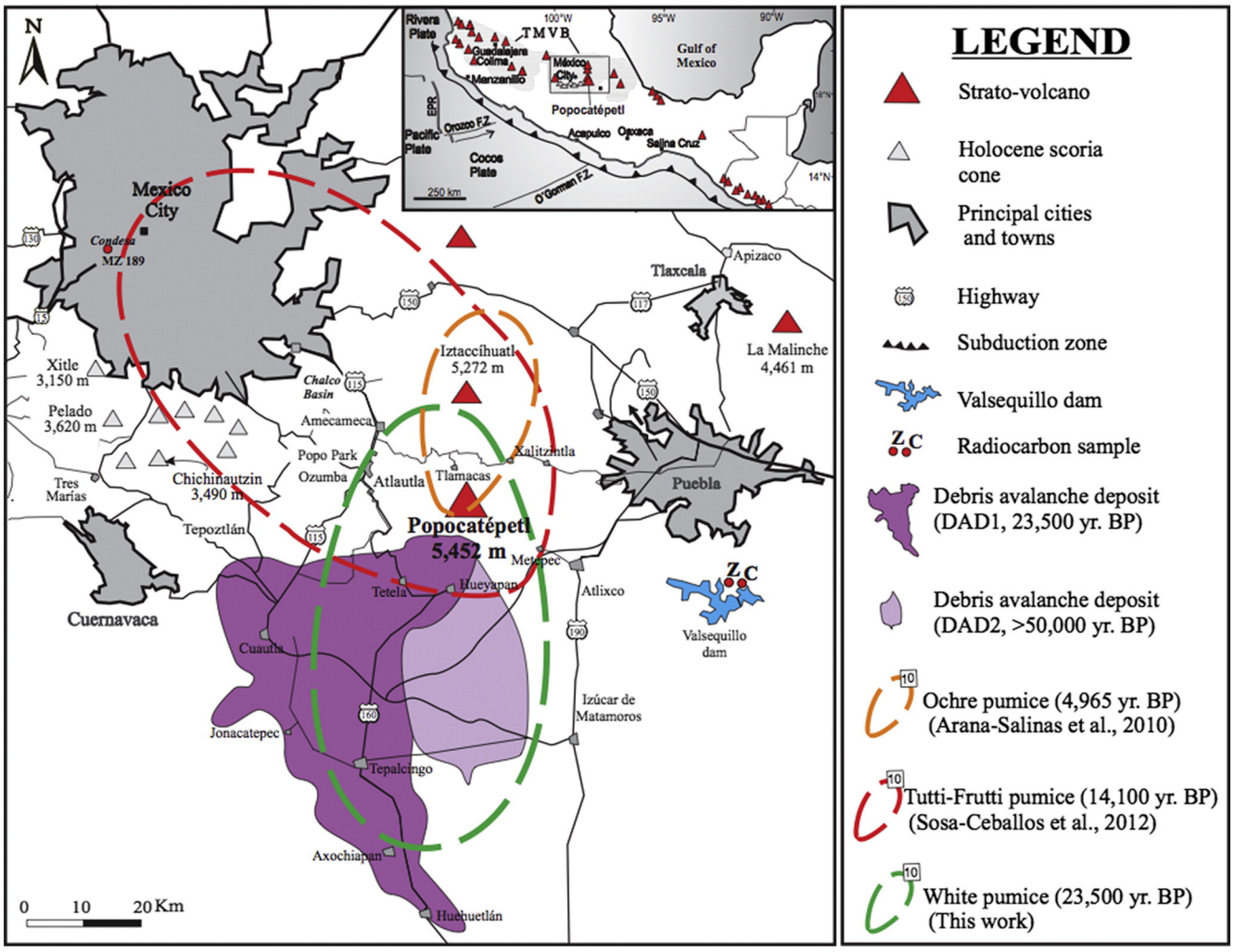

Fig. 1. Map showing major cities and towns in the vicinity of Popocatépetl volcano (modified from Siebe and Macías, 2006). 10-cm-isopachs of major studied Late Pleistocene-Holocene Plinian Pumice fallout deposits (White, Tutti Frutti, and Ochre) as well as area covered by the most recent debris avalanche deposits are also indicated. Zacachimalpa (Z) and Caulapan (C) are sites PO-98458-A and PO-98459-B respectively, where lahars derived from the White Pumice deposits containing megafaunal fossil remains have been identified and radiocarbon dated. MZ-189 denotes deep excavation at Colonia Condesa, where radiocarbon samples MZ-189-PS1 and MZ-189-PS2 were obtained. Inset shows the Trans-Mexican Volcanic Belt and its position with respect to the active subduction zone.

(De la Cruz and Siebe, 1997). The new activity has consisted mainly of pulsating emissions of ash and fumarolic gases (Love et al., 1998; Goff et al., 1998; Stremme et al., 2011) associated to subsequent episodes of rapid dome growth at the summit crater (Macías and Siebe, 2005; Gómez-Vázquez et al., 2016). This still ongoing eruptive period has prompted numerous geologic studies of the volcano revealing that Popocatépetl should be regarded as one of Mexico's potentially most dangerous volcanoes due to the highly explosive eruptions that are documented in its stratigraphic record (e.g. Siebe et al., 1996; Siebe and Macías, 2006). The modern cone of Popocatépetl is built on the remnants of previously existing cones that were destroyed by cataclysmic eruptions of the Bezymianny or Mount Saint Helens type (Robin and Boudal, 1987). The last eruption of this type occurred ~23,500 y BP (see discussion of its age in this paper). It produced an extensive debris avalanche deposit, the Plinian White Pumice (WP) fallout blanket, as well as the Tochimilco andesite lava flow (TL), all of which cover extensive areas to the south of the present cone (Figs. 1 and 2; see also Robin and Boudal, 1987; Siebe et al., 1993, 1995). Since then, Popocatéptl's present summit cone was built as a result of numerous eruptions, including at least 6 high-magnitude Plinian eruptions. Among these, the 14,100 y BP Tutti Frutti eruption was probably the most powerful and its fallout deposits were dispersed toward the NW (Siebe et al., 1999; Sosa-Ceballos et al., 2012). The most recent Plinian eruptions include the 4965 y BP Ochre Pumice (Arana-Salinas et al., 2010), the 2150 y BP Lorenzo Pumice, and the 1100 y BP Pink Pumice, all with dispersal axes toward the NE quadrant (Siebe et al., 1996; Panfil et al., 1999; Siebe and Macías, 2006). All three of these eruptions fall well within the time of human occupation of this area, and especially the last two of them impacted settlements as attested not only by numerous occasional artifact findings (Seele, 1973; Seele and Siebe, 2012) but also by a few formal and systematic archaeological excavations (Plunket and Uruñuela, 1998, 2000). The present Mexico City (70 km NW of the volcano) and the city of Puebla (40 km to the E) along with other cities and towns lie within the area of fallout from Plinian eruptions (Bonasia et al., 2014).

The catalclysmic Bezymianny (or Mount Saint Helens) type eruption (Siebert, 1984) that occurred ~23,500 ^{14}C y BP represents a major break in the Late Pleistocene eruptive history of the volcano because it marks the collapse of a large volcanic edifice that was constructed over a period of tens of thousands of years and the beginning of a new constructional cycle that led to the stepwise rise of the modern cone of Popocatépetl (Macías et al., 2012). The

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