EL MISTI STRATOVOLCANO, SOUTH PERU : ERUPTIVE HISTORY AND IMPLICATIONS FOR HAZARD ASSESSMENT

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About 900,000 people live at risk in Arequipa area 17 km away from the vent of the active El Misti stratovolcano (16°17'45"S, 71°24'30"W), in the northern part of the Central Volcanic Zone (Figs. 1 and 2). El Misti has been built on 200 to 300-m-thick ignimbrites (upper Tertiary) overlain by 200-m-thick volcaniclastic sediments (mostly debris flows and interbedded ignimbrites). El Misti encompasses two edifices: a 'modern' stratocone, to the East and SE, has been built up side by side and has overlapped in part an 'older' stratovolcano, to the West and NW.

The older stratovolcano (lower to middle ?) Pleistocene in age consists of 400-m-thick and long andesite lava flows, overlain by debris-avalanche deposits at least 100 m thick towards the West and SW. These deposits burying a piedmont in excess of 50 km^2 in area record the probable destabilization of the 'older' stratovolcano, which occurred sometime before late Pleistocene (see the scar of the probable flank failure in Figs. 1 & 2). To the SE, they intertwine with similar deposits from the extinct Pichu-Pichu stratovolcano (Fig. 1).
The bulk of the ca. 70 km^3 and 5,825 m high stratocone consists of stubby lava flows and pyroclastic debris piling up to 1.8-2.4 km in thickness. On top of the cone-shaped summit, the historical crater 500 m across and 200 m deep including an andesitic plug nests in another crater 900 m wide, whose horsheshoe-shaped walls parallel NS- and WNW-ESE-trending fractures. Both vents are located within a summit explosive caldera 1.5 km across, whose rim partly buried to the West may correspond to the scar of the probable flank failure (Figs. 1 and 2).
Based on fieldwork and interpretation of air-photos and SPOT satellite image, five units of deposits record the late Pleistocene eruptive history, as follows (Fig. 3).

(I) Lava flows, block-lava flows, and buried domes form the lower stratocone (above 3,000 m) towards the South, SW and NE. This is overlain by an old pyroclastic sequence (block-and-ash flows) and stubby lava flows which have built up the cone-shaped summit, above 4,000 m (see composition of lavas in Fig. 4).

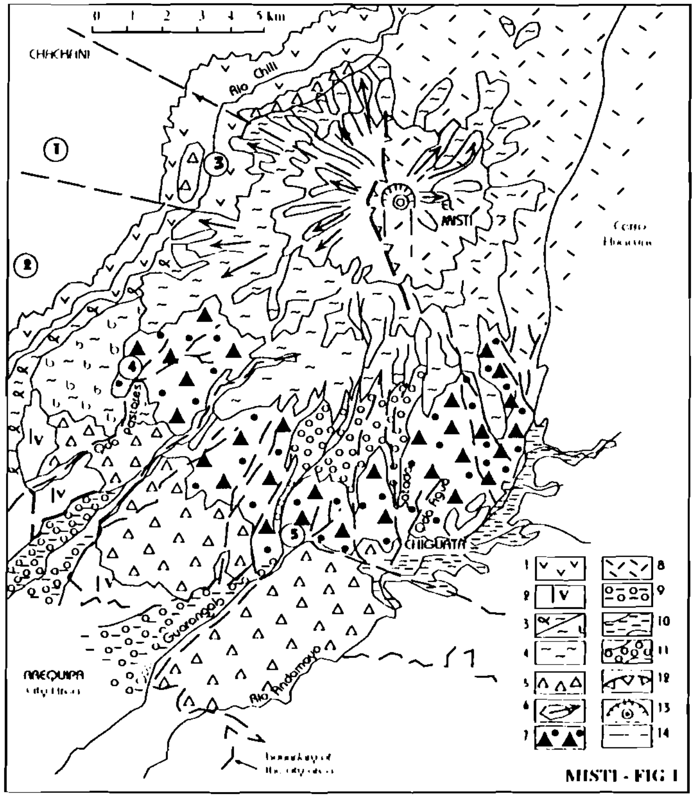

FIGURE 1. Sketch map of volcanic deposits on El Misti and in Arequipa area
1. Ignimbrites of upper Tertiary overlain by volcaniclastic sediments of Plio-Quaternary age. 2. Old lava flows (pre-Misti ?). 3. 'Older' stratovolcano (lower to middle ?) Pleistocene in age: a) andesite lava flows; b) block-lava flows. 4. Lava flows of the lower 'modern' stratocone (middle to late ?) Pleistocene in age. 5. Debris-avalanche deposits (end of middle Pleistocene ?). 6. Summit stratocone of late Pleistocene to Holocene. 7. Piedmonts built up of pyroclastic deposits (units II to V, Fig. 3). 8. Area mantled by black scoriae and ash deposits (related to the summit caldera-forming eruption ?). 9. Fans of volcaniclastic deposits in the lower radial valleys. 10. Lacustrine deposits of the (Last Glacial ?) Chiguata basin. 11. Pumice-flow deposit 1920 ± 200 yr B.P. old. 12. Scar of the probable flank failure. 13. Nested craters and plug. 14. Main fracture.

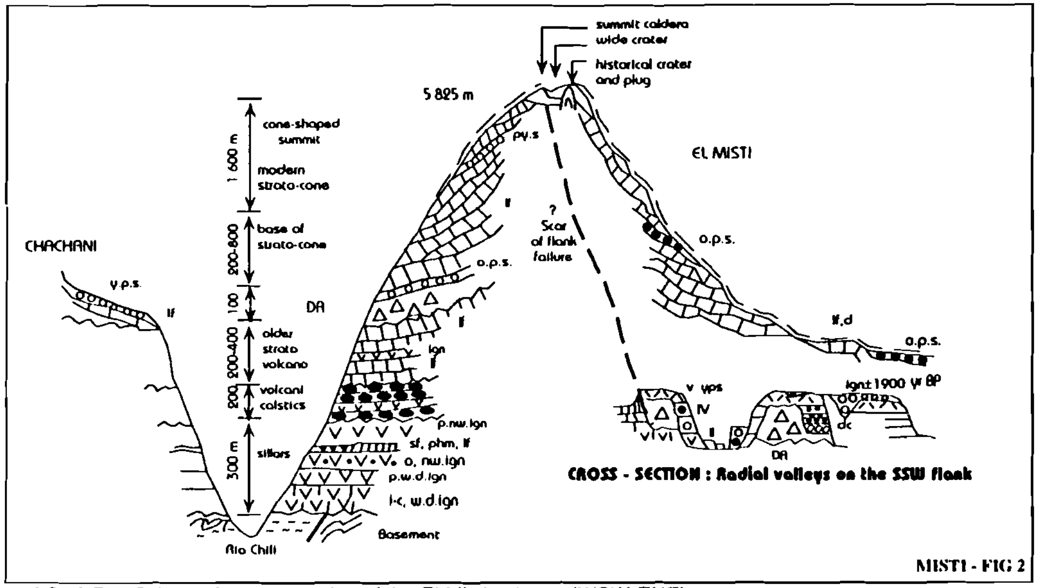

FIGURE 2. Schematic cross-section of the El Misti volcano (WSW-ENE)
Basement (Precambrian gneiss and Jurassic sediments). Sillars=ignimbrites, l-c=light-colored, p=pink, o=orange, pu=purple, w=welded, d=devitrified. sf.phm = scoria-flow and phreatomagmatic deposit. lf=lava flow. d= dome. ign=ignimbrite. DA=debris-avalanche deposit. o.p.s. / y.p.s. = old / young pyroclastic sequence.
(Right-hand corner) Schematic cross-section of the radial valleys, SSW flank. DA=debris-avalanche deposit. dc= deposit of dome collapse. III-V y.p.s.=units of the young pyroclastic sequence (Fig. 3). ign 1900 yr B.P.=radiocarbon dated pumice-flow deposit.

(II) A pyroclastic sequence (mostly scoria flows and fall) mantles the flanks of the extinct Chachani stratovolcano to the West and the North and NE Misti's flanks. Based on interspersed deposits of glacial source, this sequence can be placed close to the last glacial period.
(III) A pile of pumice or ash-flow and tephra-fall deposits, rhyolitic in composition, may reflect an explosive episode which lead to the formation of the summit caldera. Organic material on top of a brown soil within the upper part of these deposits yielded a radiocarbon age of 33,870 ± 1800/1460 yr B.P. (GrN 21574).
(IV) Block-and-ash pyroclastic-flow deposits up to 50 m thick on the south and SW flanks include interbedded pumice and lithic-rich flow deposits. They record alternated dome growth and destruction.
(V) A ≤10-m-thick pile of pumice and ashfall deposit, postglacial in age, show that El Misti has erupted explosively at least 20 times over the last ca.14,000 years. The Plinian-subplinian activity has decreased or come to rest for short periods only, as shown by poorly developped soils in ash. One pumice-rich flow deposit has formed a pyroclastic fan ≥10 km^2 in area and was channelized 12 km from vent in gorges that cut deeply the south flank (Fig. 1). Its basal pumice-fall deposit yielded a radiocarbon age of 1920 ± 200 yr B.P. (i.e., calibrated 200 yr BC-AD 200). On the surface, a ≥10-cm-thick ashfall layer witnesses to some explosive activity at A.D. 1440-1480, as refered to in historical accounts. El Misti has been reportedly active at the end of the 1700's and 1800's, while fumarolic activity at the crater plug resumed in 1949 and 1984-1985.

Stratigraphy and sedimentology point to alternating, large-scale plinian activity and dome growth for at least the last 40,000 years. Thus, the most severe volcanic hazards for the 900,000 people of Arequipa are as follows (Fig. 4).

(1) Low Plinian columns (<5 km) may cause ash fallout in the city, as shown by the approximate extent of the mid-1500's ashfall (Fig. 4). For higher columns (20-25 km) based on mapping of the 3cm and 5cm isopleth of the ca. 1900 yr B.P. plinian tephra-fall deposit carried towards Arequipa by prevailing NE winds, the thickness of the relevant layer could amount 50 cm in the city.
(2) The expected extent of the pyroclastic flows is towards the south, SW, and SSE, owing to the crater wall geometry (Fig. 4). The destruction of the summit dome can yield block-and-ash flows which are expected to travel 8 to 12 km downstream when valley-confined; thus, they might hit the NE suburbs of Arequipa. More mobile pumice flows are expected to travel another 4-8 km further downstream, as well as towards the populated Chiguata area. The pumice-flow tuff ca.1900 yr B.P. old was channelized in the radial valleys as far as the present suburbs of Arequipa, while subsequent small-volume lahars spread out further downvalley.
(3) Finally, flank failures can occur along fractures on the steep-sided West and SSE flanks of the volcano. Subsequent debris avalanches may choke the Chili valley and spread out on the southern piedmont.

References

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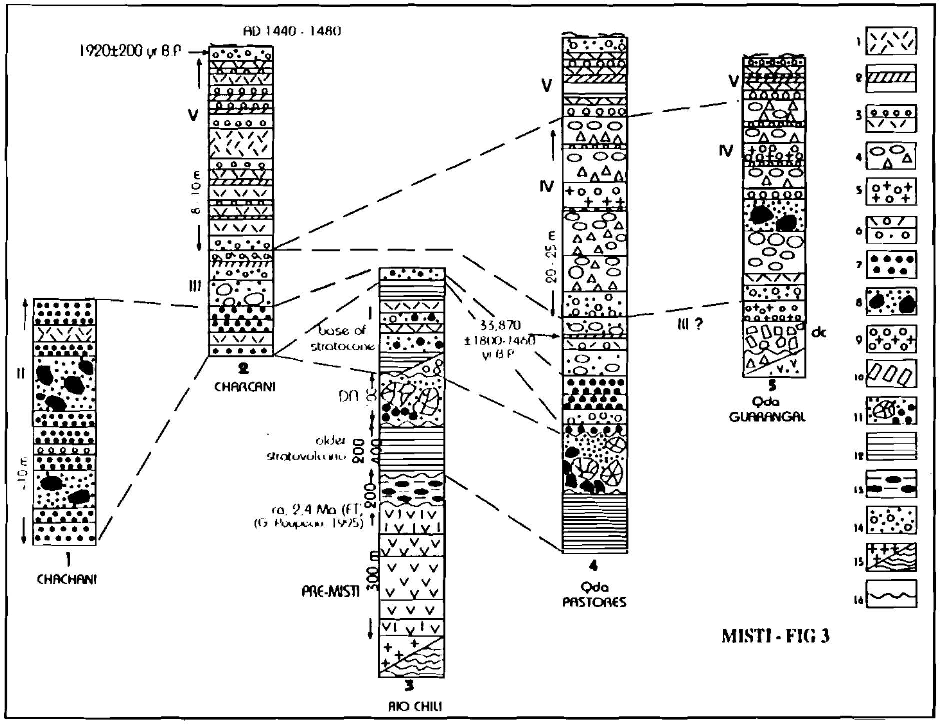

FIGURE 3. The stratigraphy of El Misti stratovolcano (measured sections in Fig. 1). Basement (15) same as Fig. 2. Pre-Misti: ignimbrites (14) and volcaniclastic sediments (13). 'Older' stratovolcano: lava flows (12) and debris-avalanche deposits (11). Lower 'modern' stratocone = Unit I, andesite or block-lava flows and old pyroclastic sequence. Summit stratocone: lava flows and young pyroclastic sequence (Units II-V). Unit II = 10: deposit of dome collapse 9:lithic-rich pyroclastic-flow deposit, 8:scoria-flow deposit, 7: scoria-fall deposit. Unit III = 6: pumice-flow and fall deposit, rhyolitic in composition. Unit IV = 5. pumice and lithic-rich pyroclastic-flow deposits, 4: block-and-ash flow deposits. Unit V = 3. Plinian pumice-flow and pumice-fall deposit, 2: poorly developed soil in ash, 1:ashfall layer AD 1540-1580. 16: stratigraphic unconformity.

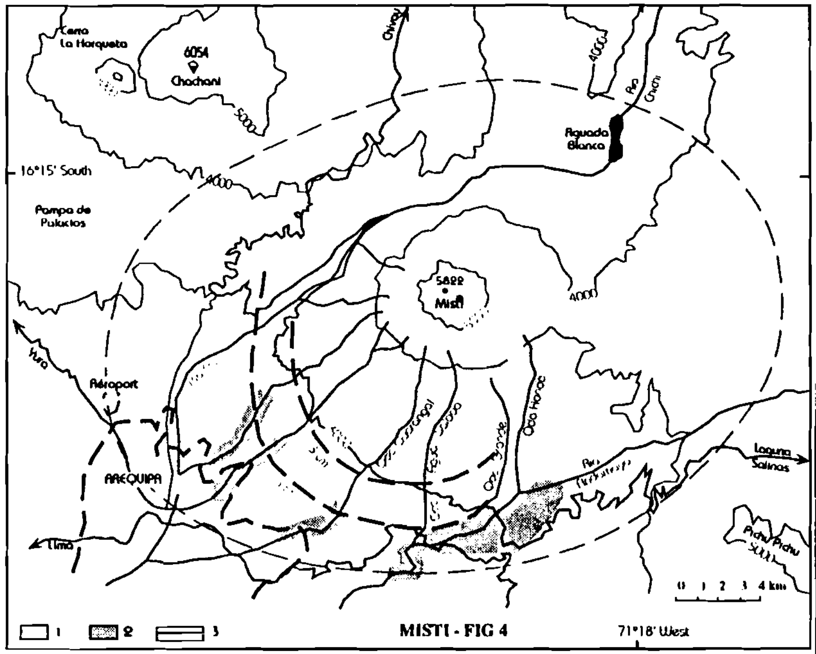

FIGURE 5. Expected extent of future pyroclastic flows and tephra-fall at Misti Circle areas (1) represent block-and-ash flows with H/L = 0.25 and an energy line of < 16° as typical values at Misti. Dashed areas (2) represent more mobile pumice flows with H/L = 0.20 and an energy line of < 13° as typical values at Misti. The elliptical shape (3) outlines the area likely to be covered by a 10-cm-thick ashfall deposit in case of a moderately explosive event alike the mid-1500's eruption. The 5-cm and 3-cm isopleths of the ca.1900 yr B.P. old Plinian eruption are also shown.