HUAYNAPUTINA VOLCANO, SOUTH PERU: SITE OF THE MAJOR EXPLOSIVE ERUPTION IN HISTORICAL TIMES IN THE CENTRAL ANDES

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The major explosive eruption in historical times in the Central Andes took place at Huaynaputina, a small volcanic center (16°37'S, 70°51'W) located in the northern part of the Central Volcanic Zone (South Peru, Figs. 1 & 2). Huaynaputina does not display a typical volcano morphology but relatively uncommon volcanic structures (de Silva & Francis, 1991): three nested funnel-like vents and ash cones located on the floor (4,200m) of a 2.5x1.5 km horseshoe-shaped caldera which reamed out the eastern edge of a volcanic plateau. The summit (4,800 m) is breached towards the East, forming an amphitheater open to the deep canyon of Rio Tambo, 6 km horizontally and 2.7 km vertically from the crater rim. Most of the caldera has been formed prior to the 1600 eruption, resembling other horseshoe-shaped scars which eat away the volcanic plateau ≥ 4,200 m in elevation (Fig. 1). Lava flows, ignimbrites, and pyroclastic deposits of no more than 500 m thick built up this high-plateau which includes one early extrusive lava dome to the south edge, and overlies the deeply dissected sedimentary bedrock of Mesozoïc age.

According to chronicles, the A.D. 1600 eruption began on February 19 after at least 4 days of intense seismic activity, while the Plinian stage lasted until February 21. Repeated ash fallout and earthquakes unil March 2 devastated 7 indian villages as far as 15 km away from vent and damaged Arequipa city 75 km away (Barriga, 1951). The bulk volume of the eruptive deposits is estimated at about 10 km^3 (Gonzales-Ferran, 1990). The deposits include: (1) a very widespread plinian fallout (Fig. 2); (2) large-volume pumice-flow deposits, including proximal lag brecciae and channelized ≥ 30 km in the Tambo valley (Fig. 3); (3) pyroclastic-surge deposits, observed on the caldera slopes and as far as 13 km in the Quebrada del Volcan (Fig. 4), and; (4) late ashfall and debris flows. An additional minor explosive event in 1667 may have contributed to the last ashfall. The plinian-fall deposits are distributed in two lobes, the most voluminous extending several hundreds of km to the West and WNW (≥ 10 cm thick in Arequipa, ≥ 3 cm at the Pacific coast 150 km due WSW), and the second several tens of km towards the North. In addition, fine white ash observed along the NW-trending Pacific coast as far as 900 km from source, was carried away by SE high-altitude winds.

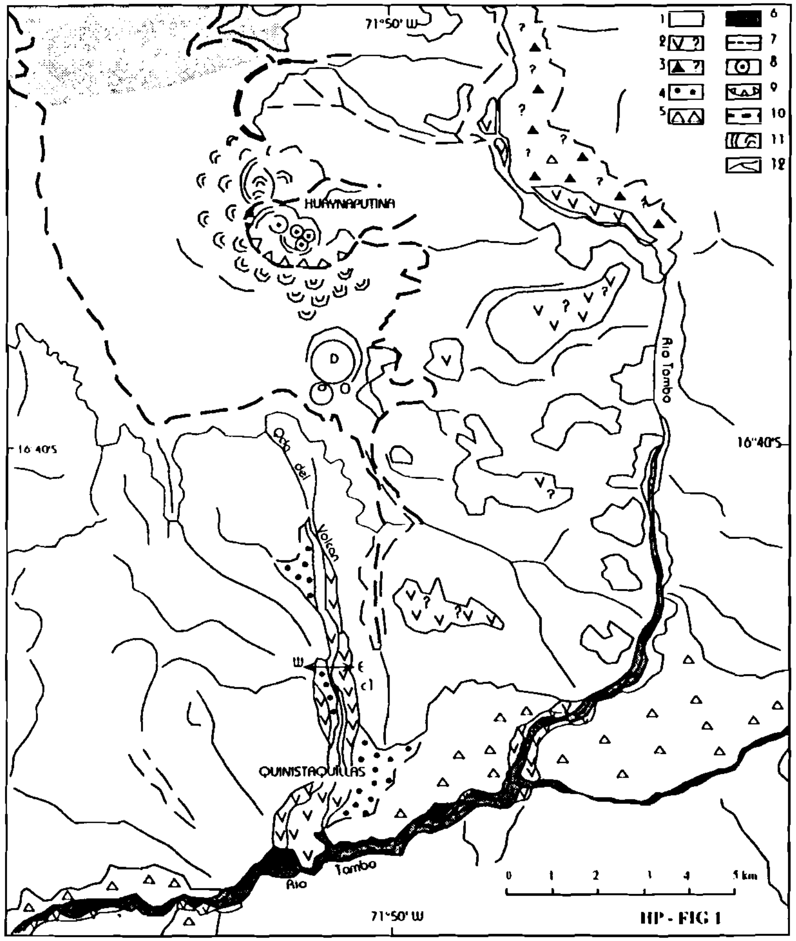

Figure 1. Schematic map of the area of Huaynaputina volcano and related volcanic deposits and features (based on one SPOT satellite image and air-photos).
1. Plinian fallout deposit: ≥ 2m thick (a) < 2m (b). 2. Ignimbrite=pumice-flow deposit, mostly channelized (? where inferred). 3. Probable debris-avalanche deposit (dashed where inferred, upper Rio Tambo). 4. Block-and-ash flow deposit prior to the A.D. 1600 event. 5. Large-scale debris-avalanche deposit from the Ticsani stratovolcano, to the East. 6. Floodplain and alluvial terraces. 7. Limit of the volcanic high-plateau (dashed where inferred). 8. Pre-1600 dome ; A.D. 1600 vents. 9. Scar of the pre-1600 caldera. 10. Fresh scar of debris avalanche ; subdued scar of landslide. 11. Ring fractures and collapse features. 12. Ridge in sedimentary bedrock. Arrow W-E in Qda del Volcan indicates location of cross-section in Fig. 4.

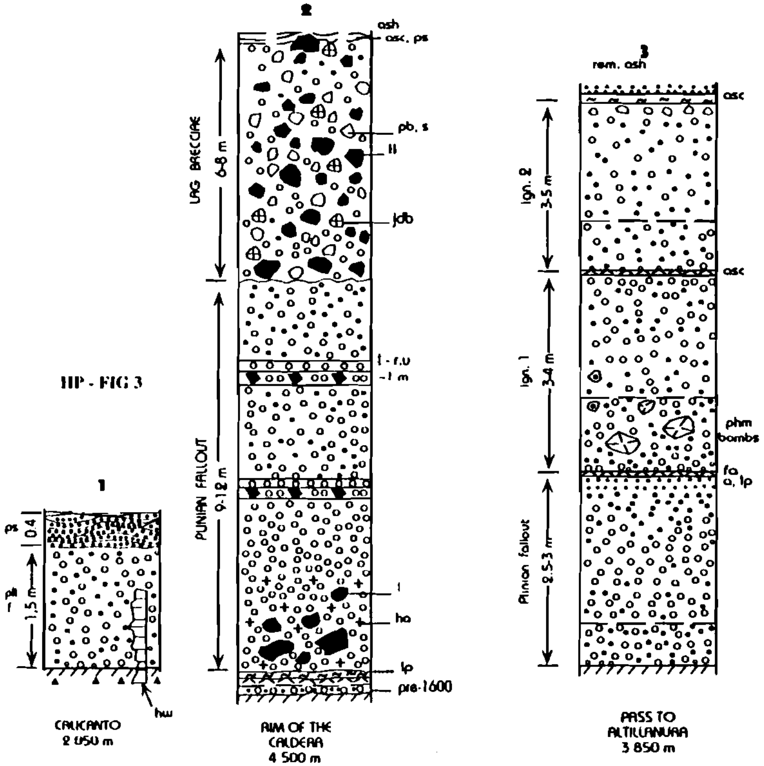

Figure 3. Measured stratigraphic section of the A.D. eruptive deposits at Huaynaputina
1. Calicanto, 2050 m, 13 km from vent: ps pyroclastic surge deposit, wall of the buried houses and tilled terraces. 2. Rim of the caldera, 4500 m, 1 km from vent (from top to base): asc, ps ash-cloud surge, pyroclastic-surge deposit; pb, s pumice blocks, scoriae; l l large lithics (accidental and accessory, including sediments); jdb juvenile dacite blocks. l-r.u. lithic-rich units. l lithics, ha hydrothermally altered lithics, lp leaves of *puna* vegetation, pre-1600 soil, removed ash and pumice lapilli. 3. Pass to altillanura, 3850 m, 5 km from vent: rem. removed ash, asc ash-cloud surge deposit, phm phreatomagmatic bombs, Ign 1, 2 ignimbrite = pumice-flow deposits.

According to preliminary field data, we infer that the pre-1600 edifice and early domes were blown away during the eruption, leading to the formation of the complex crater, the failure of the north rim of the caldera, and finally to the nested vents and low cones of silicic tephra (Fig. 1). In addition, pumice-rich pyroclastic flows and probable debris avalanches choked the upper Rio Tambo (Fig. 1). The canyon reportedly was dammed at least 28 hours, leading to two temporary lakes and subsequent catastrophic release of large-scale debris flows.

The proximal sections (Fig. 3) show the thick Plinian, massive tephra-fall deposit, overlain by lag-breccia deposit which form high and large crescent-shaped dunes protruding from the ash apron that surround the caldera rim (Fig. 1). Interestingly, the base of the tephra-fall includes a large amount of sedimentary blocks and hydrothermally altered lithic lapilli. Recurrent 1-m-thick lithic-rich units are interspered in the middle and upper part of the otherwise massive pumice-fall deposit. The medial sections (Fig. 4) show a complex pyroclastic sequence. The pre-1600 units encompass: (1) block-and-ash flow and dome collapse deposits; (2) a pyroclastic sequence including a Plinian tephra-fall deposit similar in composition to the 1600's. The A.D. 1600 sequence entails: (1) a Plinian pumice-fall deposit; (2) two to three nonwelded pumice-flow deposits, the earliest carrying phreatomagmatic bombs; (3) a pyroclastic-surge deposit showing cross-stratified bedding and dune-like features, and; (4) a late ashfall layer.
The mineral assemblage of the erupted dacite encompasses plagioclase, biotite, amphibole, magentite, and ilmenite. However, the evolution from deposit 1 to deposit 4 is correlated with significant chemical and mineralogical changes : (1) decrease of SiO_2 (65.5 to 62.8 %) and K_20 (2.9 to 2.6 %) contents, while MgO (1.7 to 2.15 %), CaO (4 to 4.5 %), Fe_20_3 (4.2 to 4.5 %) and Sr (696 to 754 ppm) increase; (2) increase of Mg/Mg+Fe of biotite (58 to 70) and amphibole (56 to 71) and of An % content of plagioclase ($An_{25\text{-}52}$ to $_{34\text{-}59}$). These preliminary results are consistent with emptying of a zoned dacitic magma chamber.

Our preliminary data preclude to indicate what caused such a catastrophic explosive eruption (VEI 6). However, we suggest two triggering processes: (1) a small amount of basaltic component exists in the tephra-fall; (2) a significant amount of hydrothermally altered lithics at the base and lithic-rich units throughout the Plinian fallout, as well as phreatomagmatic bombs in the lower ignimbrite, witness to hydromagmatic interaction. The deposits including lag brecciae and volcanic features such as funnel-like vents and landsliding of part of the caldera point to eruptive processes involved in maar-like craters and small explosive calderas. Such a large-scale explosive silicic eruption did not involve caldera collpase; however, ring-fractures and collapse features surround the vents and the northern caldera rim (Fig. 1).

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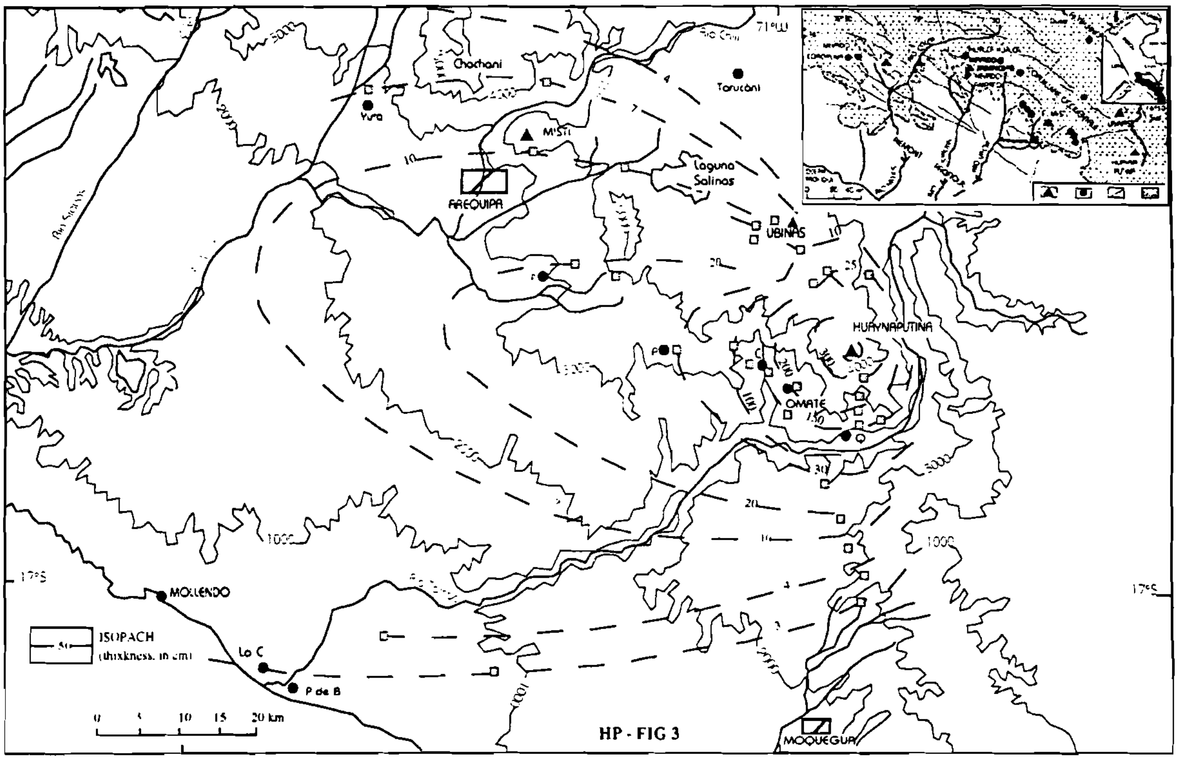

Figure 2. Schematic map showing the approximate extent of the A.D. 1600 Plinian fallout from Huaynaputina.
tephra-fall isopach, thickness in cm; x are measured sections (preliminary data, 1995).

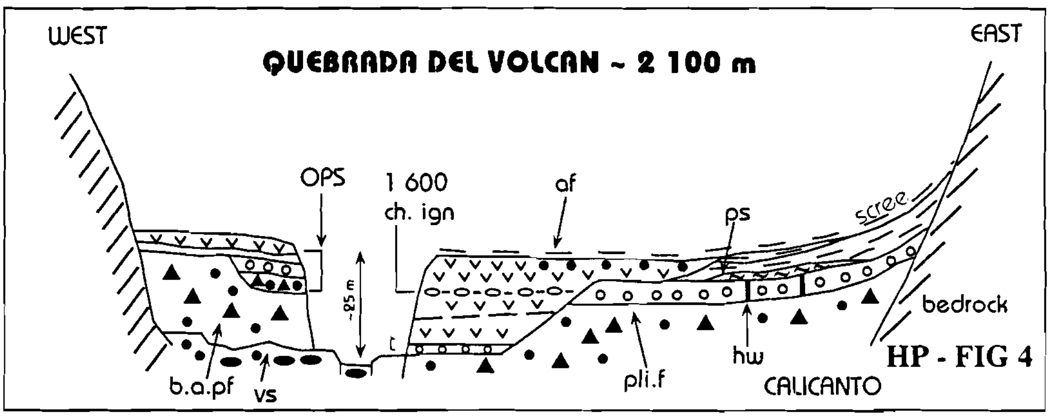

Figure 4. Cross-section of Quebrada del Volcan, 12 km South from vent (arrow in Fig. 1).
1. Pre-1600 deposits: vs volcaniclastic sediments; b-a.pf block-and-ash pyroclastic flows; OPS old pyroclastic sequence (probably lower Holocene in age). 2. A.D. 1600 deposits: Pli.f Plinian-fall deposit; ch. ign. channelized pumice-flow deposits; ps pyroclastic-surge deposit; af ashfall deposit. hw house wall of the buried Calicanto village. scree, debris talus from bedrock and removed ash.