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

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El pequeño centro volcánico Huaynaputina (Sur del Perú), lugar de la erupción explosiva más violenta de los Andes Centrales durante la época histórica
La erupción violenta (IEV 6) del pequeño centro volcánico Huaynaputina empezó el 19 de Febrero de 1600, duró 16 dias y liberó una recaida pliniana sobre más de 20000 km^2, luego ignimbritas, oleadas piroclásticas y otras recaidas menores de lapilli y cenizas. El edificio pre-existente fue destruido en parte, formando un complejo de tres cráteres y conos de cenizas adyacentes. Además, flujos de escombros devastaron los 120 km del trayecto del Rio Tambo hasta el Oceano Pacífico. Los depósitos sugieren que procesos de interacciones hidromagmáticos han jugado un papel en desencadenar la erupción Pliniana y que se han formado luego cráteres semejantes a un maar de gran tamaño. Aunque tan violenta erupción no involucró el colapso de una caldera, varias fracturas concentricas recortan el complejo de cráteres y el piso de la caldera de avalancha.

Key Words : Huaynaputina volcano, South Peru, Plinian eruption, ignimbrites

The major explosive eruption in historical times in the Central Andes took place in 1600 at Huaynaputina, a small volcanic center located in the northern part of the Central Andean Volcanic Zone (southern Peru, Fig. 1). Huaynaputina does not display typical stratovolcano features; instead, unusual volcanic structures include three funnel-like vents and ash cones nested at the bottom (4,200m) of a horseshoe-shaped 2.5x1.5 km caldera, open to the deep canyon of Rio Tambo which lies 6 km horizontally and 2.7 km vertically below the rims. Most of the caldera had been formed before the 1600 eruption at the eastern edge of a high plateau. This has been built up of lava flows and ignimbrites of no more than 500 m thick which overlie dissected sedimentary and intrusive rocks of Mesozoïc age.

According to chronicles, the 1600 AD eruption began on February 19 with a ca. 19 hour-long Plinian stage after 4 days of intense seismic activity, and included at least 9 distinct events until March 6. Repeated tephra-falls, pyroclastic surges and flows, and earthquakes devastated 7 villages in a 20 km radius from the vent and shook Arequipa city 75 km away (Barriga, 1951). The erupted tephra several km^3 in volume include (Figs. 2 and 3): (1) a widespread and voluminous plinian fallout on $\geq 20{,}000$ km^2; (2) several thin airfall layers; (3) pyroclastic-surge deposits 0.4 to 1 m thick as far as 15 km from the vent; (4) ignimbrites ≥ 0.4 km^3 including proximal lag breccia and channelized ≥ 30 km; (5) a probable co-ignimbrite ash deposit; (6) a crystal-rich airfall deposit distinguishable as far as 100 km W of the vent; (7) secondary, reworked ignimbrites, and (8) late ash-fall and debris flows.

The plinian-fall deposits are distributed in one extensive lobe ≥ 400 km to the W, SW and NW (Fig. 2) and a minor lobe ≥ 100 km to the N. Fine-grained white ash 3 cm thick as far as 400 km from source on the Pacific coast was carried aloft by prevailing high winds from the SE. Ash-fall was reported further away in Ica and Cusco to the NW, in La Paz and Potosi (Bolivia) to the NE, and in Arica (Chile) to the S (Fig. 2). In proximal sections, the 3 to 9-m-thick, massive deposit is inverse graded, then normal graded, and consists of dacitic pumice lapilli with a minor amount of hydrothermally altered lithics and crystals, while the upper part shows recurrent 1-m-thick lithic-rich units (Fig. 3). In distal sections, crystal ash increases with distance with respect to the vitric component, whereas the sparse lithic lapilli decrease rapidly both in size and amount with distance. The minerals encompass: (1) vesiculated glass shards; (2) plagioclase and quartz; (3) brown/green amphibole and biotite, and; (4) a few opaques and xenoliths.

Pyroclastic-flow deposits are preserved on the slopes of the plateau and in the small catchments whose head lies several km away from the caldera rim. The external slopes of the caldera bear large dune-like arcuate antiforms 30-50 m long and 2-5 m thick which protrude out of the apron of tephra (Fig. 1). The lag-breccia material is a mixture of lithic blocks with white, pumiceous porphyric lumps of dacite. Proximal ignimbrites consist of 2-3 beds 3-5 m thick, composed of pumice lapilli in an ash matrix with a few phreatomagmatic bombs in the lower part (Fig. 3). When valley-confined as far as 15-20 km from the vent, the 6 to 10-m-thick, nonwelded ignimbrite includes 3 to 5 ash-and-pumice flow beds. Other pyroclastic-flow deposits overlie the ignimbrite and the crystal-rich unit in the high-gradient radial valleys (Fig. 3). Most of them are 1-m-thick beds which contain a mixture of reworked ash, pumice lapilli, lithic fragments, and non-volcanic rocks removed from the near slopes.

The erupted magma is a medium-K dacite of the potassic calc-alkaline suite. The mineral assemblage encompasses plagioclase, biotite, amphibole, magnetite, and ilmenite. Three different groups of erupted lavas are observed: (1) The Plinian fallout deposit is less silica-rich (63.6% SiO_2 on average), more magnesium-rich (1.85% MgO) and contains only one plagioclase population (An30-60). (2) The ignimbrites are more silica-rich (65.2 SiO_2 on average), less magnesium-rich (1.72% MgO), and contain two populations of plagioclases (An30-40 and An45-60). A few plagiocases are zoned with a core more calcic (up to An70) than the rim (< An55). (3) The crystal-rich airfall deposit is more silica-rich and less magnesium-rich. We interpret these observations to represent an eruption which emptied a part of a zoned dacitic magma chamber.

The 1600 eruption led to the formation of the complex crater, nested vents and low cones of silicic tephra, as well as to the failure of the northern part of the avalanche caldera, which had already breached the former stratovolcano. In addition, pyroclastic flows and probably debris avalanches from the northern caldera rim choked the upper Tambo canyon, which was reportedly dammed at least 28 hours, forming two temporary lakes (Barriga, 1951). Subsequently, the catastrophic breaching of the lakes released large-scale debris flows that swept down the 120-km-long valley to the Pacific Ocean. Although our preliminary data are insufficient to understand what caused such a single violent explosive eruption (ranked VEI 6), we stress that the onset of the Plinian stage probably included hydromagmatic interactions. Evidence include the large amount of hydrothermally altered lithic component at the base and oxidized lithic-rich units throughout the Plinian fallout, the lag breccia and the phreatomagmatic bombs at the base of the ignimbrites. Although this explosive silicic eruption did not involve caldera collpase, ring-fractures cut the vents and the bottom of the avalanche caldera (Fig. 1).

Barriga V.M. 1951. *Los terremotos en Arequipa* (1582-1868). La Colmena, 426 p.

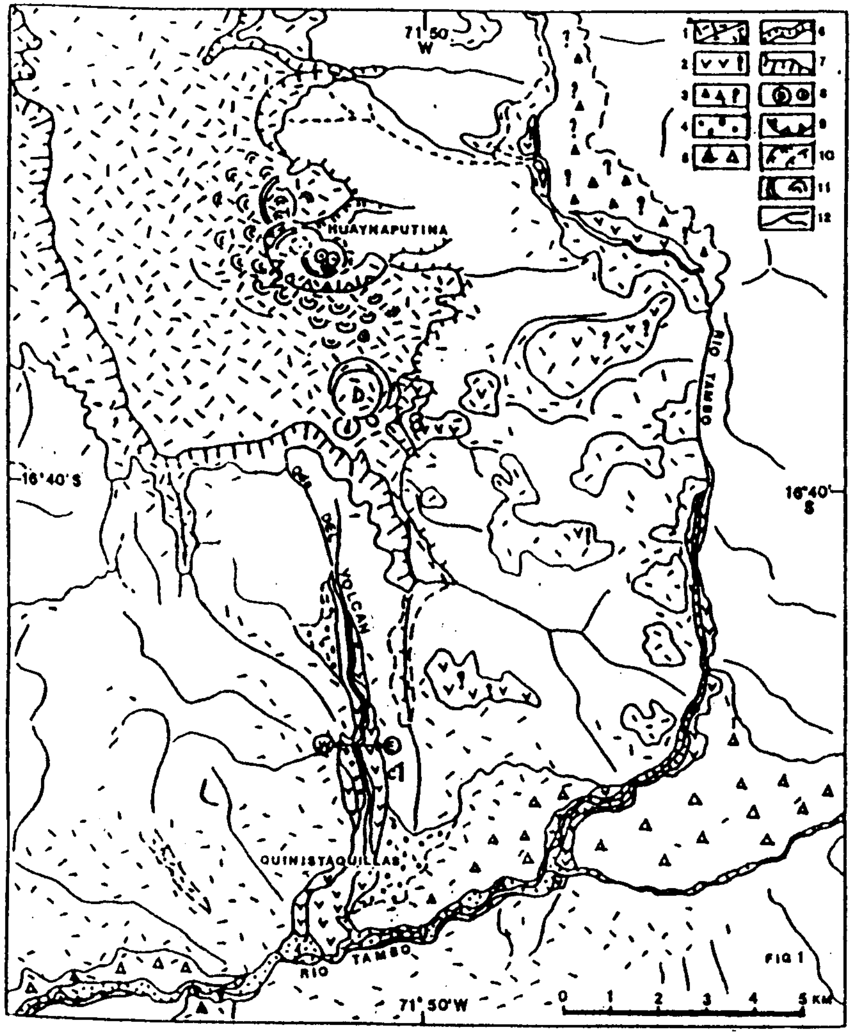

Figure 1. Schematic map of the area of Huaynaputina volcano and related volcanic deposits and features (based on one SPOT satellite image and air photos).
1. Plinian fallout deposit: ≥ 2m thick (a) < 2m (b). 2. Ignimbrite=pumice-flow deposit, mostly channelized (? where inferred). 3. Probable debris-avalanche deposit (dashed where inferred, upper Rio Tambo). 4. Block-and-ash flow deposit prior to the 1600 AD 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 AD dome ; 1600 AD vents. 9. Scar of the pre-1600 AD caldera. 10. Fresh scar of debris avalanche ; subdued scar of landslide. 11. Ring fractures and collapse features. 12. Ridge in sedimentary bedrock.

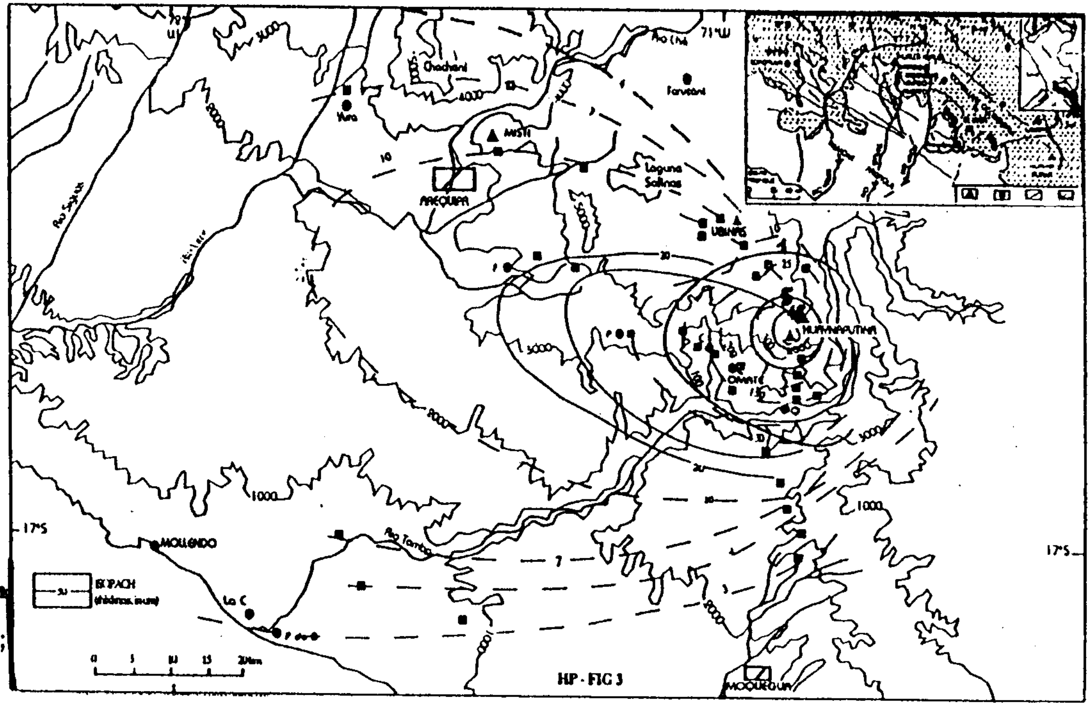

Figure 2. Schematic map showing the approximate extent of the 1600 AD plinian fallout from Huaynaputina.
Tephra-fall isopach (dashed), thickness in cm; lithic isopleths (circles), 15, 5, and 5 cm; squares are measured sections (preliminary data, 1995-96).

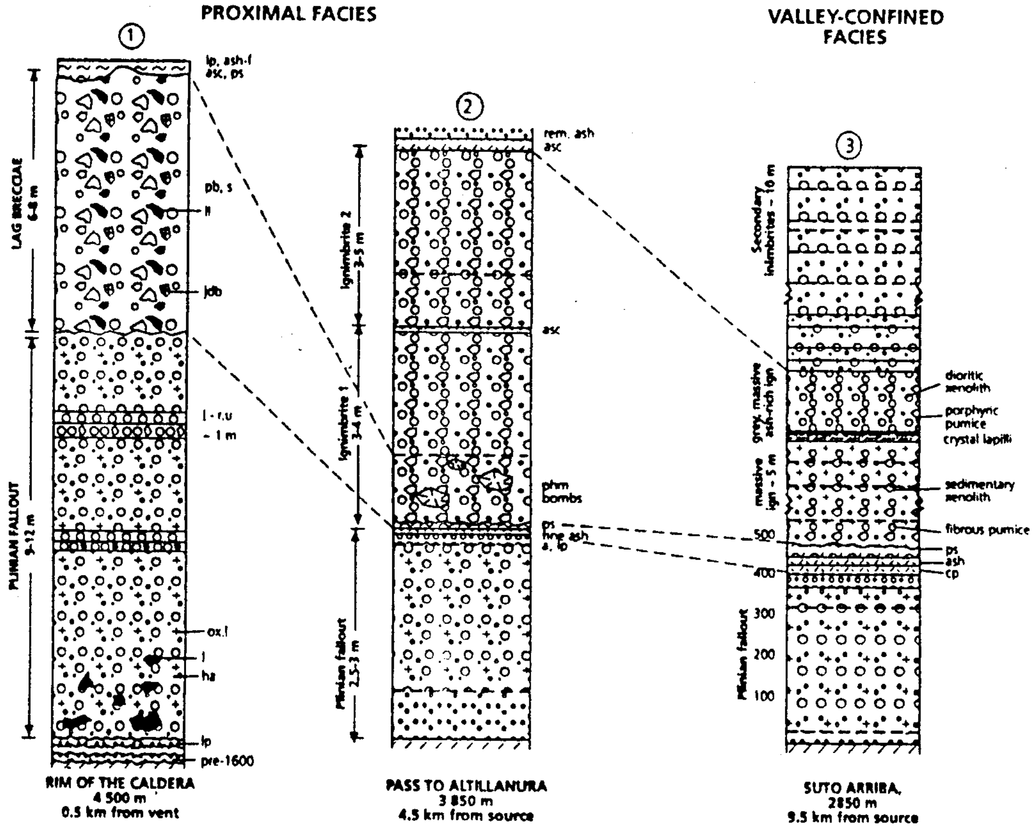

Figure 3. Measured stratigraphic sections of the 1600 AD eruptive deposits at Huaynaputina

Proximal facies: 1. Rim of the caldera, 4,500 m, 0.5 km from vent (from top to base): asc ash-cloud surge, ps pyroclastic-surge deposit; pb, s pumice blocks, scoriae; ll 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 in ash and lapilli. 2. Pass to altillanura, 3,850 m, 4.5 km from vent: rem. removed ash, asc ash-cloud surge deposit, ps pyroclastic-surge deposit, phm phreatomagmatic bombs, ignimbrite=pumice-flow deposits. *Valley-confined facies*: 3. Suto arriba, 2,850 m, 9.5 km from source. 4. Calicanto, 2,050 m, 13 km from vent: old b.a.f., block-and-ash flow deposit, hw, wall of buried house and tilled terrace. 5. Suto abajo, 2,400 m, 11.5 km from source: lp lapilli pomez. *Medial to distal facies*: 6. Escobaya, 2,070 m, 14.5 km from source. 7. Cerca Paso Santa Rosa, 4,400 m, 33 km from source. Note the crystal-lapilli airfall layer in sections 3, 5, 6, and 7.