

LATE PLEISTOCENE AND HOLOCENE TEPHROSTRATIGRAPHY AND CHRONOLOGY IN SOUTHERN PERU

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INTRODUCTION

Multidisciplinary investigations of stratigraphic sections and cores extracted from peat-bogs and lakes in the Western Cordillera of the southern Peruvian Andes, have enabled us to trace more than 40 tephras over the past 50,000 ^{14}C years. At least eight pumice-fall deposits are widespread ($>1,000 \text{ km}^2$) and voluminous ($\geq 1 \text{ km}^3$), as shown in bold squares in Table 1.

**TEPHROSTRATIGRAPHY AND CHRONOLOGY IN SOUTHERN PERU,
NORTH-CENTRAL ANDEAN VOLCANIC ZONE**

TABLE 1

VOLCANOES TIME PERIOD	SARA-SARA	COROPUNA stratovolcano and domes	ANDAHUA-HUAMBO OCROPAMPA monogenetic field	AMPATO MASSIF and NEVADO SABANCAYA lava domes	EL MISTI STRATOVOLCANO	UBINAS STRATOVOLCANO	HUAYNAPUTINA VOLCANIC CENTER	TICSIANE CUMBILLO-DOMES	TUTUPACA	YUCAMANE
AD 1500				1990-98 ph / phmag / vulc 1750 - 1784	1784-87 ph 1677	active since 1552	Feb-March 1600		1902, 1862 1802 1780	1787
HISTORICAL			AD 1400-1600 af, Chicayoc cone	af AD 1460 ± 30 ? ≥ 1680 ± 30 (HP) peak-bog	AD 1440-80 af 1677 af	af, ph, phmag 1677 af	pt, PF, pa (dacite)	Sp, pf, af	pt, af	
2000 yr BP			Andahuayla group			880 ± 60 P, pf				
HOLOCENE					AD 430 - 160 BC P, pt, PF 2300 ± 60 PF ≤ 2370 ± 90 af	Debris- avalanche deposit				
5000			2850 ± 50 st. Kayoco cone ≥ 2810-2970 ± 50 af	2770 ± 190 dt, PF 3800 ± 50 af	2770 ± 190 dt, PF 3800 ± 50 af	> 3670 ± 60			Tutupaca dome collapse	
			4050 ± 50 af Ticlio and Puca Maura cones	4750 ± 40 ps ≤ 5440 ± 40 if	4750 ± 40 ps ≤ 5200 ± 80 ps	+	+	three domes	PF	-
			Andahuayla group and Huambo		6390 ± 50 PF	> 7480 ± 40	< 7480 ± 40			
			8770 ± 50	8520 ± 80 af	8140 ± 80 PF	R, pf	R, pf	9700 ± 190	P, pf	
10,000	P, pf		Andahuayla group and Huambo	voluminous block-lava flows	~ 10,600 ± 240	11,280 ± 70 11,480 ± 220	P, pf, ps	11,600 ± 80	pf	
LATE GLACIAL			Orcopampa group of subdued cones and lava flows	↑ ↓	TP1 pt, TP2 pt, TP3 da pt					
15,000					~ 13,640 ± 330	14,680 ± 200				
					TP4 and, pt, contemporary to glacial retreat					
20,000						20,960 ± 380/360				
25,000						24,840 ± 480	PF			
30,000			27,200 ± 300 af		31,200 ± 1330 PF 33,400 ± 2800/2160 PF 33,900 ± 3200/2360 PF					
35,000			37,370 ± 1010/11180 af		36,300 PF 39,680 ± 3370/1170 PF 40,200 ± 650/740 PF					
40,000					43,970 ± 1180/1030 PF					
45,000	>44,500				47,350 ± 2100/1700 PF 48,640 ± 2220/1170 PF				44,000 ± 2130/2910 pf	
50,000 yr BP	>49,200									

at: ash fall; pt: pumice fall; PF: pyroclastic flow; ps: pyroclastic surge; af: acoria flow; phc: phreatic; phmag: phreatomagmatic; at: atombolian
vulc: vulcanian; sp: subplinian; P: plinian; aind: andesite; da: dacite
voluminous tephra-fall deposit > 1 km³

LATE PLEISTOCENE TEPPHRA

Late Pleistocene tephra have been dated on the west flank of Nevado Sara Sara between ca. 49,200 and 44,500 yr BP and ca. 44,000 yr BP on the south flank of Yucamane. Nevado Coropuna has probably been active before the Late Glacial; ashfalls in a soil section outside of the Last Glacial Maximum moraines yielded ¹⁴C ages of ca. 27,200-37,370 yr BP. The composite Misti edifice comprises a stratovolcano termed Misti 1, partially overlapped by two stratocones termed Misti 2 and 3 (≤ 112 ka), and a summit cone Misti 4 ≤ 11 ka. Sustained explosive eruptions have delivered at least 12 pumice falls during the past ca. 50,000 years (Thouret et al., 2001b).

LATE-GLACIAL AND HOLOCENE TEPHRAS

Two cores extracted from the *salar* of Laguna Salinas, 35 km east of Arequipa, include 7 tephra-fall deposits from Huaynaputina, Misti, and Ubinas over the past 15,000 years (Juvigné et al., 1997). Two recent tephra falls are found around the Tiesani domes: a dacitic pumice-fall deposit of 0.4 km³ has been dated ca. 11,600 yr BP; bombs and pumice preceding the youngest dome overlie the AD 1600 Huaynaputina ash. The recent explosive behaviour of Ubinas produced several tephra falls, including two widespread plinian pumice falls. The pumice-fall deposit >7840 yr BP and the ca. 980 yr BP-old pumice-fall deposit have a volume >1 km³ and may be linked to the formation of the summit caldera (Rivera et al., 1998). The peat sequence in the Sallalli peat-bog 10 km SE from the Nevado Sabancaya includes 4 tephra-fall layers: the AD 1600 Huaynaputina ash, an AD 1200-1400 Sabancaya/Ampato ash, a thin black ash probably from Misti ca. 2,370 yr BP, and a Sabancaya/Ampato ash of ca. 8,550 yr BP (Juvigné et al., 1998).

HISTORICAL TEPHRAS

The last subplinian explosive episode ca. 2,300-2,050 yr BP at Misti produced pumice-fall and flows ca. 1 km³ in volume. Spanish chronicles refer to an explosive eruption ca. AD 1440 and 1470: the small volume 'Pachacútec ash' affected the Incaic towns of Cayma and Chiguata (Thouret et al., 1999a, 2001a). The AD 1600 Huaynaputina plinian eruption produced the most widespread and voluminous (12 km³) pumice-fall deposit in the Andes in historical times (Thouret et al., 1999b). Tephra falls, pyroclastic flows, and surges disrupted life ~60 km around the volcano and ashfall was reported 250-500 km away in south Peru, west Bolivia and north Chile. Persistent eruptions of Nevado Sabancaya have dispersed a small volume of ash from May 1990 until 1998 as far as 20 km towards the east (Thouret et al., 1995, 2001b).

CONCLUSIONS

In sum, 1) heavy ashfall can recur every 500 to 1500 years on average but small ashfall can occur on a 100-years basis; 2) voluminous pumice-fall deposit can occur every 2000 to 4000 years on average; 3) three voluminous (≥ 1 km³) plinian eruptions occurred over the past 2,000 years; (4) the large-scale plinian and ignimbritic eruption of Huaynaputina produced 12 km³ of tephra and caused havoc and famine in southern Peru 400 years ago.

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