

GEOLOGY, GEOCHEMISTRY AND RECENT ACTIVITY OF THE HUDSON VOLCANO, SOUTHERN CHILE

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RESUMEN

We present first geological and geochemical results of a comprehensive study on Hudson volcano and its Recent activity. An Upper Pleistocene unit forms the basis of Hudson volcano. This activity period produced predominantly andesitic pyroclastic flows interbedded with basaltic lava flows forming a caldera like structure. Holocene magmatic activity produced basaltic cones and andesitic to dacitic eruption centers oriented along the main Holocene fracture zones.

Lava flows and pyroclastic products are calcalkaline and range in SiO₂ from 49 to 68 wt.% with medium to high-K character. We distinguish two basalt types. The older, Upper Holocene to Late Pleistocene basalts (type-1), when compared with the younger, Late Holocene to Recent basalts (type-2), have higher X_{Mg} values (50-61), K/Rb (400-520), Ba/La (20-50), and Rb/Cs (60-95) ratios, and lower TiO₂ (>1.5 wt.%), La/Yb (2.3-3.3), Rb/Sr (0.02-0.04) ratios. Type-1 has lower ⁸⁷Sr/⁸⁶Sr (~0.7036), ²⁰⁶Pb/²⁰⁴Pb (~18.48), and higher ¹⁴³Nd/¹⁴⁴Nd ratios (~0.51286) than type-2. Late Holocene to Recent basalts of type-2 have lower X_{Mg} values (38-45), K/Rb (320-380), Ba/La (10-17), and Rb/Cs (36-65), but higher La/Yb (3-4), Rb/Sr ratios (0.04-0.06), and TiO₂ (1.6 to 2.3 wt.%) than type-1. The higher Sr, Nd, and Pb isotopic ratios of the type-2 suggest an additional crustal component. Most andesites and dacites originated from the basaltic type-2 by fractional crystallization in a closed system without further crustal contamination.

The youngest activity of Hudson volcano started with a fissure eruption at the 8th of August 1991. These basaltic phase (8/8-10) located at the western caldera rim produced fallout and lava flows. The following proximal andesitic phase (8/12-15) with eruption centers in the SW part of the glacier filled caldera ejected tephra in a SE-directed plume up to 1000 km SE (Malvinas Islands). Recent gas activity has

apparently increased since August 1991. We observed columns up to 500 m altitude in a crater-like depression around the andesitic eruption centers (8/12-15). Glacier melting by the strong geothermal activity has intensified the mud flow production in the direction to Huemules valley.

KEY WORDS: Southern Andes, Chile, volcanism, volcanic activity, geochemistry, Quaternary.

INTRODUCTION

Active continental margins are characterized by predominantly intermediate to felsic calcalkaline volcanism produced by differentiation and interaction of the mantle-derived basaltic melts with the continental crust. In the Andes basaltic volcanism is restricted to the southern section of the Southandean Volcanic Zone (SVZ). It is controlled by the Liquiñe-Ofqui fault zone (LOFZ) that extends between 39° and 46°S. Hudson volcano is located at its southern end about 300 km NE of the plate triple junction formed by the Nazca, Antarctic and South American plates. The magmatic activity of Hudson volcano is related to the subduction of a Nazca plate segment. The rise of this segment is oriented parallel and in front of the Chile trench. The trench is filled by sediments which were drilled by ODP Leg 141 up to Pliocene formations (BEHRMANN et. al 1992). This implies subduction of young, hot, oceanic crust including sediments. The continental crust is 30 to 35 km in thickness. Plutonic rocks of the Patagonian Batholith and Paleozoic metamorphic rocks form the exposed basement. The latter rocks show a continental isotopic signature (PUNKHURST et al. 1991). Both rock units could have contaminated the primary upper mantle melts of the Hudson volcano by sediments of the subducted slab or/and by intracrustal AFC processes.

GEOLOGY

Geological field work was carried out in the austral summers 89/90, 91/92 and 92/93. Our satellite image investigation on the Hudson basement shows a Holocene fracture framework striking 103°, 125°, and 18-25°. The latter are oriented parallel to the LOFZ. This fracturing was produced by the Recent Chile rise collision with the continental margin. The dikes, eruption centers and cones are located on these lineaments. Andesitic lava flows (each one up to 50 m thickness) and basaltic to andesitic lava flows (each one up to 20 m thickness) form the basal Upper Pleistocene unit of the Hudson. The basic Hudson unit document alternating effusive and highly explosive activity. It is exposed on the North-Western and partly on the Eastern side forming a caldera-like structure. In the Holocene, twelve eruption centers were formed at different locations of the whole volcanic area of about 95 km². Basaltic cones and fissures were formed especially on the western and eastern caldera rim. The eruptions centers located in the glaciated Pleistocene caldera were often highly explosive probably due to phreatomagmatic processes forming products of andesitic to dacitic compositions.

GEOCHEMISTRY

Major and trace elements of 70 samples from different volcanic and basement units were obtained by XRF. The trace elements, Cs, Th, U, Ta, Hf, Sc and the REE were determined by INAA from 20 samples. The isotopic ratios of the elements Sr, Nd, and Pb were detected from 11 selected samples (KILIAN & HEGNER 1993).

The effusive and explosive volcanic products are calcalkaline and range in SiO₂ from 49 to 68 wt. % with medium-K to high-K character. Two types of basalts can be distinguished. The older, Upper Holocene to Late Pleistocene basalts (type-1) have higher X_{Mg} values (50-61), K/Rb (400-520), Ba/La (20-50), and Rb/Cs (60-95) ratios, and lower TiO₂ (>1.5 wt.%), Rb (13-20 ppm), La/Yb (2.3-3.3), Rb/Sr (0.02-0.04) ratios than the younger, Late Holocene to Recent basalts (type-2). Type-1 has lower ⁸⁷Sr/⁸⁶Sr (~0.7036), ²⁰⁶Pb/²⁰⁴Pb (~18.48), and higher ¹⁴³Nd/¹⁴⁴Nd ratios (~0.51286) than type-2. In comparison with geochemical calculations of BRANDON et al (1989), HAWKESWORTH et al. (1992), and KELLER et al. (1991) trace element pattern for type-1 are consistent with a derivation of a partially melted slab mixed with material from a peridotitic source in the mantle wedge. The isotopic data are consistent with a depleted mantle source contaminated with 1-2 % of old continental crust.

Late Holocene to Recent basalts of type-2 have lower X_{Mg} values (38-45), K/Rb (320-380), Ba/La (10-17), and Rb/Cs (36-65), but higher La/Yb (3-4), Rb/Sr ratios (0.04-0.06), and TiO₂ (1.6 to 2.3 wt.%) than type-1. Higher Sr, Nd and Pb isotopic ratios suggest an additional crustal component as exposed on the surface. Most andesites and dacites originated from the basaltic type-2 by fractional crystallization of plagioclase (An₉₀ to An₃₅), olivine (Fo₉₀ to Fo₅₅) and augite in a closed system without further crustal contamination as indicated by similar K/Rb, Ba/La, and isotopic data as basalt type-2.

RECENT ACTIVITY

The basaltic eruption phase of 8-9 August 1991 (GVN Bulletin v. 16, no. 7-12) was located at the ice covered (20-30 m thickness) western caldera rim forming an elliptic fissure vent about 2.5 km long, 0.3 km wide, and 0.2 km deep trending N 25°W. Constant fumarolic activity with intense sulfur odor was observed since August 1991. The basaltic eruption phase produced 1.0-1.5 km³ (DRE) (IPPACH & SCHMINCKE, 1993) of fallout material, lava, and spatter flows. Lava flows extend max. 3.5 km beside the Huemules glacier from the N flank of the fissure vent. Additionally, lava debris flows and aa-like flows were observed at the N flank extending up to 2.5 km from their source. At the western inner caldera rim lava and spatter flows extend down the slope into a 300 m deep depression of the ice covered caldera surface. The inner part of the WNW caldera rim partially collapsed and slid into the caldera. The thickness of the basaltic fallout layers decrease from about 500 cm near the source to 1 cm at a distance of 50 km in direction to the N. The proximal andesitic eruption phase of 12-15 August 1991 (GVN Bulletin, v. 16, no

7-12) was located in the SW part of the glacier filled caldera. The 17-18 km high eruption column was sheared by strong winds into a narrow SE-directed plume transporting 2.5-3.0 km³ (DRE) tephra (IPPACH & SCHMINCKE, 1993) to at least 1000 km SE. A large SO₂-rich cloud, ca. 1500 kton of SO₂, circled the south polar region twice in 7 days (DOIRON et al. 1991). In the SW part of the caldera crater-like depressions filled by lakes of 800 and 650 m diameter are indicating the existence of two eruption centers of the andesitic phase. This area of 5 km² is surrounded by an intensively cracked glacier.

During the austral summer of 91/92 pyroclastic material was reworked into the lower NW part of the caldera leaving deposits up to 50 m thickness. In the winter of 1992 the pyroclastic material was covered by snow, which is now compacted to 2-3 m thickness. Recent gas emission and increasing geothermic activity is producing a strong melting of the ice in an area of 10 km² around the plianian eruption centers. In this zone gas columns from different locations reaching up to 500 m altitude were observed. One phreatic gas eruption (February 1993) produced an ash fan of reworked pumice material 10 km to the E. Consequently, mud flow production is still increasing. In erosional channels of the glacier volcanoclastic material is flowing to the SE of the caldera following the Huemules glacier. This implies a permanent risk for the repopulated Huemules valley.

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