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THE PUYUHUAPI VOLCANIC GROUP, SOUTHERN ANDES (44°20'S): GEOLOGICAL AND GEOCHEMICAL ANTECEDENTS

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Introduction

The Puyuhuapi Volcanic Group is a set of nine minor eruptive centers (MEC) located at 44°16'-44°22'S/72°31'-72°37'W, near Puyuhuapi village, Aysén Region (Chile) (Fig.1).

This set of MEC is part of the southern province (41°30'S-46°S) of the Southern Andean Volcanic Zone (SSVZ; 41°30'S-46°S), together with the stratovolcanoes Yate (41°48'S), Hualaihué (41°53'S), Hornopirén (41°53'S), Huequi (42°23'S), Michinmahuida (42°48'S), Chaitén (42°50'S), Corcovado (43°11'S), Yanteles (43°28'S), Melimoyu (44°04'S), Mentolat (44°41'S), Cay (45°03'S), Maca (45°06'S) and Hudson (45°55'S). The SVZ is separated from the Austral Volcanic Zone (AVZ, 49°-55°S) by a region (46°-49°S) lacking Quaternary volcanism. This region is also where the Chile Rise intersects the continent and the Nazca-Antarctic-South-American triple junction is located.

The objective of this paper is to present geologic, petrographic and geochemical antecedents of the Puyuhuapi Volcanic Group and discuss the possible origin and evolution of its magmas.

Geology and Petrography

Four centers of the Puyuhuapi Volcanic Group are aligned along the northwestern edge of the Puyuhuapi fjord (western alignment), four are aligned between the Puyuhuapi village and the Risopatrón lake (eastern alignment), and one is isolated. The latter is located on the eastern edge of the Puyuhuapi fjord, about 6 km south of the village. The eastern and western alignments have a N40°E direction and are separated by a distance of 2 km (Fig.1). The centers forming these alignments are pyroclastic cones, emplaced upon a basement of tonalites, diorites and gabbros, which is part of the Patagonian Batholith **(1)**. The isolated center of the Puyuhuapi Volcanic Group consists of a basaltic lava flow, also erupted from a N40°E fracture. Most of these cones are

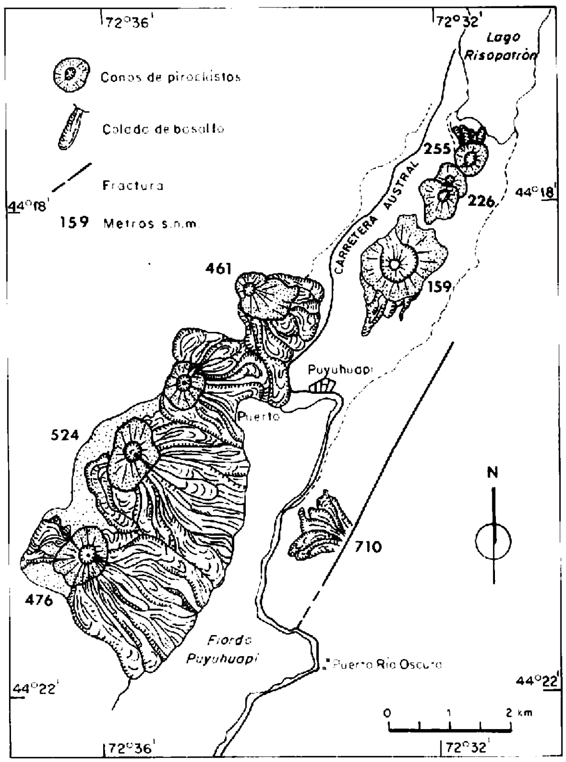

FIG. 1. Sketch map of the Puyuhuapi Volcanic Group, Southern Andes (44°16'-44°22'S)/(72°31'-72°37'W), showing the eastern and western alignments and the location of the isolated center.

biggest rises 120 m above its base. The southernmost cone in this alignment is also the largest. It is a truncated cone, 60 m high. The diameter of its base is 1250 m and that of its crater is 700 m. A new pyroclastic cone, 59 m

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high, has grown within this crater.

In general, the activity that produced these MEC was first fissural and later became centralized. While the fissural activity of the western alignment produced lava flows that reached the Puyuhuapi fjord, its centralized activity formed the pyroclastic cones.

The eruptive activity that produced the MEC of the eastern alignment was probably sub-aquatic (phreatomagmatic). This activity would have dammed the Puyuhuapi fjord, creating the Risopatrón lake.

Structurally, the volcanic activity of Puyuhuapi took place along N40°E fractures, which are parts of the Liquiñe-Ofqui fault zone. The fracture where the eastern alignment is located has been designated the Puyuhuapi-Río Frío fault **(2)**. West from Puyuhuapi, the Liquiñe-Ofqui fault zone produced an intense tectonic foliation in the basement rocks.

Taking into account the excellent preservation of the Puyuhuapi pyroclastic cones and disposition of the lava flows, in respect to the rocks of the basement, it is reasonable to assume that the Puyuhuapi activity is post-glacial and took place during the Holocene.

The material erupted from these centers is monolithologic and consists essentially of olivine basalts with a large number of empty vesicles. Their texture is porphyritic, with magnesian olivine phenocrysts (8-10%), small phenocrysts of clinopyroxene (less than 0.2%) and less than 2% of calcic plagioclase. The olivine phenocrysts are euhedral to subhedral, 0.4 to 2.5 mm in diameter, and do not exhibit reaction rims. The groundmass ranges from hyalopylitic to fluidal pylotaxitic and contains plagioclase microlites, granules of olivine, opaque minerals and basaltic glass.

Geochemical Considerations

According to their SiO_2 and K_2O contents (48.61-49.46% and 1.14-1.18%, respectively), the Puyuhuapi volcanic rocks can be classified as K-rich calc-alkaline basalts. However, because of their relatively high Na_2O contents (3.11-3.29%), these rocks can be also considered as alkaline basalts. Actually, the Puyuhuapi basalts may be unique among the basalts of the western part of the SVZ in that they are nepheline-normative (0.1-2%).

The Puyuhuapi basalts are comparatively rich in TiO_2 (1.50-1.55%) and have MgO contents (7.30-8.45%) that are higher than those of most Southern Andean basalts, excepting those basalts from the Rucapillán MEC (39°S; MgO=9.5%) **(3)**, some basalts from the Osorno stratovolcano (41°06'S; 10.5%; Fig. 2), and one basalt from the Puyehue stratovolcano (40°30'S), which has a MgO content (14.32%) similar to that expected in magmas in equilibrium with mantle peridotite **(4)**. This suggests that, in spite of their relatively high MgO abundance, the Puyuhuapi magmas underwent differentiation processes that included, at least, olivine fractionation.

Compared to stratovolcano basalts from the western part of the SVZ (e.g., Villarrica, Puyehue, Osorno, Hualaihué, Corcovado, Cay, Maca), the Puyuhuapi basalts are enriched not only in K, but also in other incompatible elements such as Rb and La (Fig. 2). However, the abundance of these elements in the Puyuhuapi basalts is lower than the abundance they have in MEC located in the Southern Andes back-arc, between latitudes 38° and 39°S **(5)**. For example, the Laguna Blanca basalts, which are similar in MgO contents to the Puyuhuapi basalts, may have K_2O contents equal to 2.42%.

According to previous studies **(6, 7)**, in the western part of the SVZ of the Andes, between latitudes 39°-46°S, there would exist at least two types of basalts: Type-I, which are depleted in incompatible elements, and Type-II, that are enriched in those elements. Figures 2 shows that the Puyuhuapi basalts belong to the second group. Both types of basalts can be found in stratovolcanoes as well as in minor eruptive centers **(7)**.

The REE patterns of the Puyuhuapi basalts are intermediate between those of Hualaihué (type-I) and Hudson (type-II) basalts (Fig. 3), being similar to the latter in the abundance of La and to the former in the abundance of Yb. Therefore, their La/Yb ratios are higher than those of Hualaihué and Hudson basalts. In fact, the La/Yb and La/Sm ratios of the Puyuhuapi basalts are one of the highest among basalts from the western part of the Southern Andes, being similar to those of San José andesites **(8)**, located in the northernmost part of the Southern Andes, where the continental crust is 50-60 km

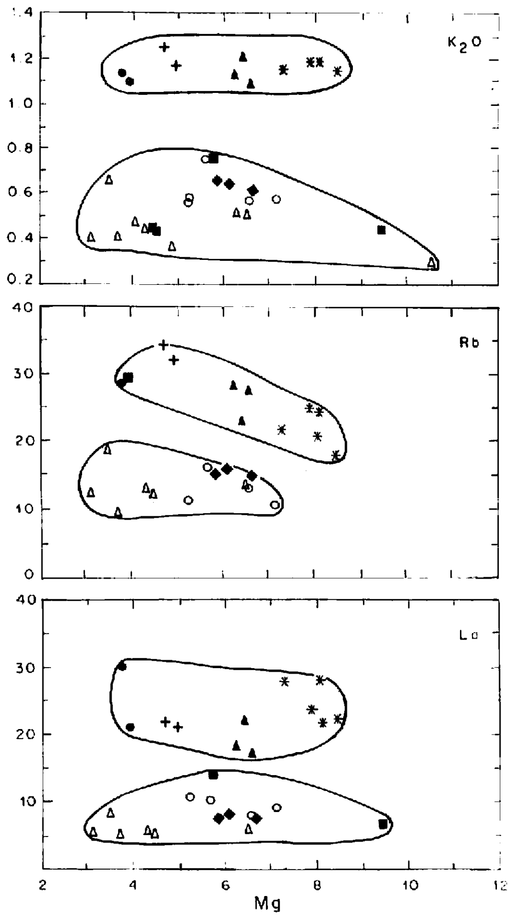

FIG. 2. K, Rb and La versus MgO for the Puyuhuapi Volcanic Group rocks ( ) compared with the abundances of these elements in other basalts from the SVZ of the Andes. These diagrams show that the Puyuhuapi basalts, like those basalts from the MEC Huililco and Pichares ( ), and basalts from the stratovolcanoes Lanín ( ), Michinmahuida and Hudson ( ), belong to the group of SVZ basalts that are enriched in incompatible elements (type-II basalts).

thick. The high La/Yb and La/Sm ratios of the Puyuhuapi basalts suggest that their primary magmas would have been generated by a lower degree of melting than those of Hualaihué.

The Ba/La ratios of the Puyuhuapi basalts are among the lowest in SVZ basalts, being slightly higher than those of oceanic island basalts (OIB; Fig. 4). This suggests that the mantle zone where the primary magmas of Puyuhuapi originated experienced a low degree of aqueous influx from the subducted oceanic crust, producing a low degree of melting. This could explain the enrichments of these magmas in incompatible elements and the high La/Yb and La/Sm ratios. It is possible that phlogopite, which has been detected in peridotites from Pali-Aike **(9)**, has participated in the melting process. It is also possible that part of this enrichment has been produced by contamination of the subcrustal magmas

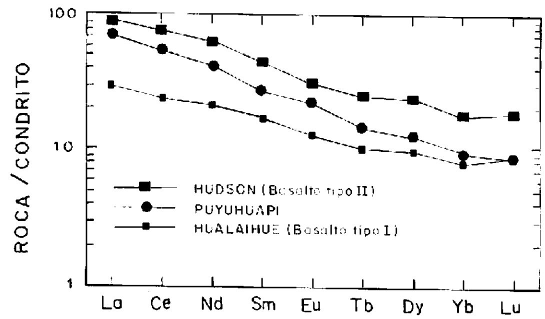

FIG. 3. REE chondrite normalized pattern of a representative basalt from the Puyuhuapi Volcanic Group compared with the REE patterns of a Hualaihué basalt (type-I) and a Hudson basalt (type-II). It can be appreciated that the La/Yb and La/Sm ratios of the Puyuhapi basalt are significantly higher than those of the Hualaihué and Hudson basalts.

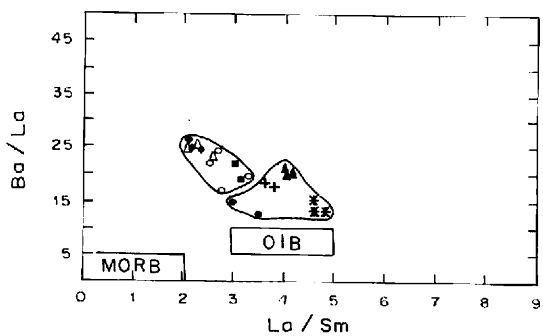

FIG. 4. Ba/La versus La/Sm diagram for samples from the Puyuhuapi Volcanic Group and several other SVZ basalts compared with OIB (oceanic island basalts) and MORB (mid-ocean ridge basalts). Type-I basalts tend to have higher Ba/La and lower La/Sm ratios than type-II basalts. The highest La/Sm ratio and one of the lowest Ba/La ratio is presented by the Puyuhuapi basalts. Type-II basalts, including the Puyuhuapi basalts, overlap with the OIB in La/Sm ratios, but have higher Ba/La ratios. Symbols as in figure 2.

with crustal magmas generated by partial melting in the volcanic conduit, during the magma ascent to the surface (10).

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