



## THE VILLARRICA-QUETRUPILLAN-LANIN VOLCANIC CHAIN: A REVIEW AND PROBABLE SIGNIFICANCE IN THE SOUTHERN ANDES, 39.4°S, CHILE.

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### INTRODUCTION

The Southern Andes are part of a geotectonic active boundary between the oceanic Nazca plate and the South-American continental plate. At latitude 39.4°S, and within the central petrographic province of the SVZ (CSVZ=37-41.5°S), there exists an important NW-SE volcanic chain that includes, among others, the composite stratovolcanoes Villarrica, Quetrupillán and Lanín. This volcanic chain is controlled by a major N55-60°W fracture that represents a crustal weakness. This fracture would be responsible of the westward displacement, in 18 km, and the morphologic change of the Liquiñe-Ofqui fault zone (LOFZ). Probably, the N55-60°W fracture corresponds to a transcurrent fault which could be currently active.

The basement of this chain consists of: a) Cretaceous and Miocene plutonic rocks, b) sedimentary and volcanogenic sequences assigned to the Panguipulli Fm (Triassic), Curarrehue Fm (Lower Cretaceous?), Trapatrapa Fm (Miocene) and c) Plio-Pleistocene volcanic sequences.

The structural system of the region includes N10-20°E; E-W and N 55-60°W fractures. The N10-20°E and N 55-60°W fractures are the most important ones. The former is related to the dextral Liquiñe-Ofqui Fault Zone (LOFZ), which runs along the Andean Cordillera, between latitudes 38°S and 46°S, for about 900km. The latter set controls the distribution of the Villarrica-Lanín volcanic chain, which comprises the

following five volcanic centers: Villarrica, Cordillera El Mocho, Quetrupillán, Quinquilil and Lanín. This chain is parallel to those of Chillán and Puyehue-Cordón Caulle volcanoes, that are displayed according to the main compressive direction.

### THE STRATOVOLCANOES

Villarrica volcano is one of the three most active volcanoes in South America. Actually, it is the only one of the volcanic chain that has fumarolic as well as eruptive activity. It has had 59 eruptions since 1558. For this reason, it has been the subject of numerous geological and geophysical studies, which started in 1976. The height of Villarrica is 2847m a.s.l. and about 2000 m above its base. It covers an area of 500 km<sup>2</sup>, and essentially consists of three superimposed units: Villarrica-1, -2 and -3. Villarrica-1 is the oldest unit, probably Upper Pleistocene in age and was a large composite stratovolcano that underwent a collapse, generating an elliptic caldera 6.5 x 4.5 km. An extensive ignimbrite is associated with this caldera whose age is >90.000 years (pre-last glaciation). Villarrica-2 is a composite stratovolcano, built on the NW side of the caldera, intra to post-glacial in age (<15000 years); and its sequence, formed mainly by lavas, includes at least, ten mainly scoriaceous pyroclastic flow deposits, two of them with volumes and extensions typical of ignimbrites (>5km<sup>3</sup>). The last pyroclastic flow deposit (Pucón) formed a 2.2 km wide caldera. Within this caldera started, about 3.700 years ago, the building of the actual cone (Villarrica-3). This is a young composite volcano, 400 m high above its base. The latter unit includes all the historic products of this volcanic center.

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From its beginning, Villarrica volcano has emitted more lavas than pyroclasts. The SiO<sub>2</sub> content of these products ranges between 51 and 57%, with a

predominance of basalts and basaltic andesites. It calls the attention, that Villarrica, like its neighbour Llaima volcano, exhibits extremely large pyroclastic flows of basaltic andesite composition, which are rare throughout the world. Villarrica-2 shows alternating sequences of lavas and pyroclastic flows and surges, that evidence dramatic fluctuations in its eruptive behaviour, changing from effusive to highly explosive (phreatoplinitic). This phenomena is, at present, under detailed study.

The Cordillera El Mocho is a small, old and eroded composite stratovolcano whose altitude is only 1774 m.a.s.l. (~800 m above its base). It is located between Villarrica and Quetrupillán volcanoes. Its geology is practically unknown, although some basaltic and basaltic-andesitic lavas has been recognized.

Quetrupillán is a large volcanic complex whose height is 2.360 m a.s.l. It consists of a composite stratovolcano, nested calderas and numerous pyroclastic cones, domes and maars, covering a surface of about 400 km<sup>2</sup>. On the basis of current geological and geochemical studies, four units have been recognized: a) an old sequence (Quetrupillán-1), pre-last glaciation, that includes old eroded stratovolcanoes and calderas; b) a volcanic complex (Quetrupillán-2), Intra-glacial in age, formed by lavas and ignimbrites that overlie the previous unit; c) Quetrupillán-3, Late-glacial in age, is a broad, partly eroded stratovolcano, with basaltic to dacitic lavas and pyroclasts, whose truncated cone exhibits a 3 km diameter circular caldera, and d) Quetrupillán-4, Postglacial recent parasitic domes and cones with related lava flows, mainly dacitic. The composition of the products of Quetrupillán volcano varies from basalt to dacite (51-68% SiO<sub>2</sub>). These products were erupted since the Upper Pleistocene to the Recent. According to some writers, Quetrupillán would have had eruptions during the XIX century.

Quinquilil is a small, old and eroded composite stratovolcano. It is not very well known. Its height is 2052m a.s.l. and its top is a sharp volcanic neck. According to preliminary studies, the composition of the lavas is mainly basaltic.

Lanín volcano is located in the SE extreme of this volcanic chain. It is also a composite stratovolcano,

with an almost perfect conic shape. Its height is 3774 m a.s.l. and 2500 m above its basement. It covers an area of 220 km<sup>2</sup> and has an approximate volume of 180 km<sup>3</sup>. Current geological studies, suggest that this volcanic center has at least four units : an old one, pre-last glaciation in age (Lanín-1), that underlies an intraglacial sequence (Lanín-2), the Postglacial cone, which represents the main unit (Lanín-3), and a summit dome with related lavas, together with recent pahoehoe lava flows and some parasitic scoria cones (Lanín-4). This modern stratovolcano has an almost bi-modal composition, exhibiting basaltic (~51% SiO<sub>2</sub>) and silicic-andesite lavas (60-66% SiO<sub>2</sub>), with little lavas of intermediate composition. No historic eruptions are related to Lanín volcano.

## DISCUSSION AND QUESTIONS

- 1.- The geology and geochemistry of the volcanoes that form part of this chain is quite different. For example, the SiO<sub>2</sub> content of Villarrica volcano ranges between 51-57%; that of Quetrupillán is continuous and varies between 51-68% and Lanín shows an almost bi-modal composition: 51% and 60-65%.
- 2.- Lanín has simultaneously erupted, in recent times, fluid pahoehoe-type basaltic lavas together with viscous silicic andesite blocky lavas.
- 3.- The volcanoes of this chain have different geological-structural evolution. For example, while Villarrica volcano has at least two caldera stages, Quetrupillán shows several nested calderas and Lanín seems to have only one caldera.
- 4.- Quetrupillán volcano, having several calderas, still has not been recognized any large pyroclastic flows like Villarrica.
- 5.- The Villarica-Lanín volcanic chain is controlled by a major N55-60°W fracture that represents a crustal weakness. This fracture would be responsible of the westward displacement, in 18 km, of the Liquiñe-Ofqui fault zone. According to current studies, probably, this fracture corresponds to an inverse transcurrent fault which is currently active.

- 6.- The of the N55-60°W fracture trend within the Central Depression, would represent the northernmost limits of the the Valdivia-Loncoche-Paillaco tectonic block, formed by metamorphic basement. This block penetrates into the Andean Cordillera interrupting the Depression. The extension of the N55-60°W fracture into the Coastal Range seems to be responsible of the interruption of the Coastal batholith southward. In addition, it coincides with the submarine canyon north of Mocha island. The seismic activity within the Valdivia-Loncoche-Paillaco tectonic block has been intense since 1988, suggesting that this block is currently active.
- 7.- During the Recent, the volcanic activity has apparently migrated from the SE extreme of the chain (Lanín volcano) toward the NW extreme (Villarrica volcano). It necessary to investigate the truthfulness of this hypothesis.
- 8.- There seems to exist spacial, structural and genetic relationships between the volcanic chain and the numerous monogenetic basaltic cones (Caburga, Huelemolle, Redondo, Relicura) and thermal springs (Menetúe, Palguín, Cajón Negro, Liquiñe) of its neighbourhood. The nature of this relationships is discussed in another paper.

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