Calbuco (Central Southern Volcanic Zone, Chile): a hazardous volcano

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Calbuco is one of the three most dangerous volcanoes in Chile (Andean Southern Volcanic Zone (SVZ)). Its recurrent explosive eruptions threat a rapidly expanding touristic and economic region as witnessed by the recent 2015 sub-Plinian eruption that occurred nearly without warning and caused significant damage to the local communities. Several parameters that are crucial for improving volcanic hazard assessment such as the depth of magma storage, the composition, including volatiles, of erupted magmas that dictates viscosity and thus potential explosivity, and reconstruction of the magma plumbing system can be derived from petrological data. Calbuco is also distinguished by hornblende-bearing assemblages that contrast with the anhydrous parageneses of most Central SVZ volcanoes. Here a detailed petrological model of the magmatic system beneath Calbuco is proposed. Geochemical data acquired on a hundred samples collected in the four units of the volcano display no secular compositional change suggesting a steady magmatic system since ~300 ka. The parent magma is a tholeiitic Al_2O_3-rich (20 wt. %) basalt (Mg# = 0.59) that initiated a differentiation trend straddling the tholeiitic/calc-alkaline fields and displaying a narrow compositional Daly gap. The higher H_2O content of the basalt (3-3.5 wt. % H_2O at 50 wt. % SiO_2) compared to neighboring volcanoes resulted in amphibole crystallization. This characteristic is interpreted as inherited from the primary mantle melt and possibly results from a lower degree of partial melting induced by the mantle wedge thermal structure. Although macrocrysts are not all in chemical equilibrium with their host rocks and were thus presumably unlocked from the zoned crystal mush and transported in the carrier melt, the bulk-rock trend follows both experimental liquid lines of descent and the chemical trend of calculated melts in equilibrium with amphibole (AEMs). These contradictory observations can be reconciled if minerals are transported in near cotectic proportions. The AEMs overlap the Daly gap revealing that the missing liquid compositions were present in the storage region. Geothermobarometers all indicate that the chemical diversity from basalt to dacite was acquired at a shallow depth (210-460 MPa). We suggest that differentiation from the primary magma to the parental basalt took place either in the same storage region or at the MOHO.