Fallout deposits of the 22-23 April 2015 eruption of Calbuco volcano, Southern Andes

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Abstract

The 22-23 April 2015 eruption of Calbuco volcano generated a series of pyroclastic deposits, among them a fallout distributed towards the NE. Four distinct layers were distinguished within the fallout deposit. The lower two layers (0 and 1 in this work) are associated to the first pulse of the eruption in the evening of April 22nd, while the upper two layers (2 and 3) are associated to the second pulse that occurred early on April 23rd.

The fallout pumice (both vesicular and dense juveniles) has porphyritic texture with plagioclase, orthopyroxene and clinopyroxene phenocrysts, within a glassy vesicular groundmass. Preliminary whole rock chemical analyses show a medium K basaltic andesite composition (54.6 – 55.5 % SiO_2), while microprobe analyses show that the glass composition ranges from andesite to dacite (60.1-64.0% SiO_2).

The estimated total deposit volume of both episodes is estimated in 0.38 km^3 (non-DRE). According to our estimations, approximately a 40% was emitted during the first pulse and 60% during the second episode.

Key words: Fallout, Calbuco, 2015 eruption, Southern Andes

1 Introduction

Calbuco is an active and hazardous volcano located in the southern Andes of Chile (Stern et al., 2007), whose last eruption before the April 2015 event, occurred in 1961 (Petit Breuilh, 1999). Its evolution is mainly characterized by the extrusion of silicic andesite lavas and domes and their associated pyroclastic flows (mainly block-and-ash and blasts), as well as cold and hot lahars (López et al., 1992; Hickey-Vargas et al, 1995; Castruccio et al., 2010; Castruccio and Clavero, 2015; Sellés and Moreno, 2011). A distinctive hummocky terrain is well developed on its lower northern flank associated to two sector collapses that affected the volcano in postglacial times (Clavero et al., 2008). According to its evolution, geochemistry and historical eruptive activity, Calbuco is considered to be one of the most hazardous active volcanoes in the Chilean Andes (Petit Breuilh, 1999; Clavero et al., 2008; Castruccio and Clavero, 2015), as it has generated subplinian eruptions in historical times (1893-1895; 1929 and 1961) as well as suffered sector collapses in the Holocene.

2 22-23 April 2015 eruption

Calbuco volcano started a new eruptive cycle during the 22 of April at 18:05 local time. Although reported seismicity increased above background levels only a couple of hours before the beginning of the eruption, regional reports (SERNAGEOMIN, 2015a) indicate a rise in the number of VT events beneath the volcano during the previous months. The eruptive column height of the first pulse reached 16 km in a few minutes (SERNAGEOMIN, 2015b). This first eruptive pulse lasted 1.5 h, with a plume dispersion to the NE. On 23 April at 1:00 local time, a second eruption generated a column that reached 17 km of altitude (SERNAGEOMIN, 2015c, d). This episode lasted 6 h approximately with the same plume dispersion to the NE than the first one. During these 2 pulses, pyroclastic flows reached 8 km from the vent in the NE and SW flanks and lahars reached the Chapo lake in the S flank (SERNAGEOMIN, 2015e).In the next days the activity decreased with sporadic events which generated weak plumes (< 2km high). On 30 April, at 13:08 local time a third pulse was generated with a 3-5 km column high and a SE dispersion. In the following weeks the eruptive and seismic activity decreased gradually and on 28 May the alert level was lowered to yellow.

3 Eruptive stratigraphy of the April 22-23, 2015 eruption on the NE flank

The 22-23 April eruption generated a series of pyroclastic and lahar deposits distributed around the volcano. The following stratigraphic units, included in this work, correspond to those identified on the N-NE flanks of the volcano, in the Río Blanco-Río Hueñu Hueñu-Ensenada area.

In this sector the units identified and shown in Fig. 1A correspond initially to a fallout deposit formed by 4 subunits (described in more detail below). Within this

fallout deposit, specifically between the second and the third units, a series of at least 8 pyroclastic density currents were generated which partially inundated the Río Frio-Río Blanco valleys (more detailed description of these deposits can be found in Clavero et al, this congress). These PDC deposits are overlain by the third and fourth subunits of the fallout deposit, and partially eroded (and dissected) by a series of lahar deposits, most of them of secondary origin, forming a pyroclastic terrace in the valley up to 20 m thick.

4 Fallout deposits

4.1 Petrography

Four distinct layers were distinguished in the eruption fallout deposits. They are listed from base to top as 0 to 3. According to the hypothesis made in this work, layer (0) together with layer (1) were formed by the first pulse of the eruption in the evening of April 22nd, while layer (2) and layer (3) correspond to the products of the second pulse that occurred early on April 23rd.

Layer (0) has grayish juvenile fragments, as well as reversely graded lithics and juveniles. Juvenile fragments are pumiceous, subangular, and show some phenocrysts (mainly pyroxene and plagioclase) within a glassy semi-vesicular groundmass.

Layer (1) has brownish pumices and grayish lithic fragments. The deposit shows reversely-graded lithics and juveniles. Juvenile fragments correspond to dense subangular pumices. They have the same petrographic features as in layer (0). This layer contains the larger juvenile fragments within the whole fallout deposits.

Layer (2) has brownish pumices and grayish dense juvenile fragments, has a normal grading of lithics and juveniles only at the base. Pumices have similar petrographic features as those in layers (0) and (1).

Layer (3) has dark grayish dense juveniles, grey lithics, and scarce highly vesicular white pumices. It shows a reverse grading in juveniles. Dense juveniles are subangular and show some phenocrysts (mainly pyroxene and plagioclase) within a poorly-vesicular glassy groundmass. Highly vesicular pumices are whitish, subangular and have a quite different mineralogy composed by plagioclase, amphibole and orthopyroxene.

The lower two layers (0 and 1) constitute 47% of the whole fallout deposit thickness, whereas the upper two layers (2 and 3) constitute the other 53% of the deposit.

The fallout pumice has porphyritic texture formed by plagioclase (15-20% vol.; 0.2-2.5 mm), orthopyroxene (5% vol., 0.1-2.0 mm), clinopyroxene (1-2% vol., 0.1-0.5 mm) phenocrysts, within a glassy vesicular groundmass with opaque minerals (1-2% vol., ~0.2 mm). The plagioclase phenocrysts commonly show 50 um-width overgrowth rims, and an overall normal zoning patterns. The groundmass shows banding given by different vesicularity degrees, ranging between 10% vol. in a brownish glass up to 25% vol. in a fresh glass. The latter bands also show glomeroporphyritc textures with plagioclase-orthopyroxene assemblage (Fig. 1B).

4.2 Grain size

A proximal sample located at ca. 6 km from the vent, was sieved to analyze the characteristics of the deposit according to Walker parameters (1971). All layers show modes between -3 and -2 Φ. The deviation in the deposit layers range between 1.05 and 1.4, and correspond to well-sorted deposits. On the other hand, layer 3 has a higher proportion of fine particles than the other layers (Fig. 2).

4.3 Geochemistry

Preliminary whole rock chemical analyses were conducted on 4 samples from levels 2 and 3 (grey). The samples are medium-K basaltic andesites. The SiO_2 content is 54.6 – 55.5 wt.% and MgO content is 3.6 – 4.1 wt.%. These contents fall inside the field for Calbuco volcano according to López-Escobar et al. (1995) and Sellés and Moreno (2011).

Preliminary microprobe data of glass and mineral analyses were done on selected samples. The glass composition ranges from andesitic to dacitic (60.1-64.0 wt.% SiO_2), with mean values of 62.7 wt.% and 61.2 wt.% for samples from levels 2 and 3 respectively. Plagioclases are typically normally zoned with ranges of An 75.8-90.3 for cores and An 58.9 – 72.8 for overgrowth rims. Ortopyroxenes are very uniform in composition and fall in the Enstatite field (Wo2.4-3.3 En65.4-69.8 Fe26.9-31.3) with slightly more En-rich rims. Clinopyroxenes fall in the augite field (Wo42.7-43.4 En40.6-41.9 Fe15.0-16.3) with no apparent zonation.

4.4 Distribution of the fallout deposit

By analyzing satellite images and our field data (57 field check points in proximal areas + 39 in distal areas, obtained by Argentinian colleagues collaborating in future studies), it was possible to establish that the fallout deposit was distributed mainly to the NE from Calbuco volcano. The maximum thickness of the deposit in the studied area was 54 cm at 5 km from the eruption vent. The 30, 20, 15, 10, 5, 1 and 0.1 cm isopachs of the whole deposit are shown in Fig. 3. The orientation of the isopachs axes is approximately 35 degrees (N35E).

4.5 Volume estimates

The deposit volumes for each pulse are difficult to calculate mainly because in distal areas it is not possible to identify each layer. The total volume for the two eruptive pulses using isopachs of the whole deposit is 0.38 km^3, using the Weibull fit (Bonadonna and Costa, 2012). The exponential method with 2 segments gives a total volume of 0.29 km^3. The power law method gives 0.28 km^3 using

an integration limit of 400 km. This gives a range between 0.28 and 0.38 km^3 for the two pulses of 22-23 April. If we extrapolated the ratios of deposit thicknesses between the two pulses found in proximal areas to the distal facies, and used the maximum total volume estimated (0.38km^3) we would obtain that the volume for the first pulse is in the order of 0.16 km^3 and 0.22 km^3 for the second pulse (Fig. 4).

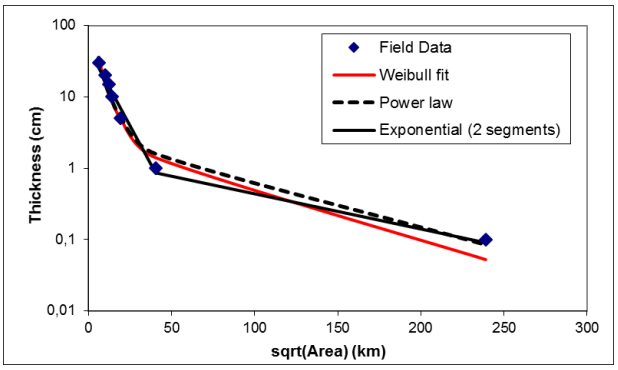


Figure 4. Thickness vs square root of area enclosed by isopachs for the whole deposit. The curves are the fits used to estimate the total volume.

5 Discussions

The fallout deposits of the 22-23 April eruptions show at least 4 units with different grain-size distributions and textural characteristics. Based on stratigraphic relationships with pyroclastic flow deposits (Clavero et al., this volume) and eruption reports, we correlate units 0 and 1 with the first pulse (22 April) and units 2 and 3 with the second one. The second pulse marks a shift in both the style of the eruption (with the increasing occurrence and magnitude of pyroclastic flows) and juvenile textures, with the appearance of denser and more crystalline clasts and a higher content of fine-grained material in the upper layer (3), that could reflect higher fragmentation degree during the latest phases. Work in progress regarding the stratigraphy, grain-size, mineral composition and textures will help to clarify the origin of these shifts in eruptive style.

The volume obtained with the Weibull method is considerably larger than the results obtained with the exponential or power-law methods. This could be due to the lack of very proximal data (< 5 km from the vent) which prevents to identify the proximal segment in the exponential method and the uncertainty of the total extent of the deposit, which makes the choosing of the integration limit in the power-law method problematic. According to Bonadonna and Costa (2012), the Weibull function can overcome to some extent these problems and we believe the 0.38 km^3 (0.15 km^3 DRE) is the closest value of the 3 methods to the actual volume of material ejected during the first two pulses of the eruption on April 22-23.

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c. (REAV) Año 2015 Abril 22 (22:30 HL)
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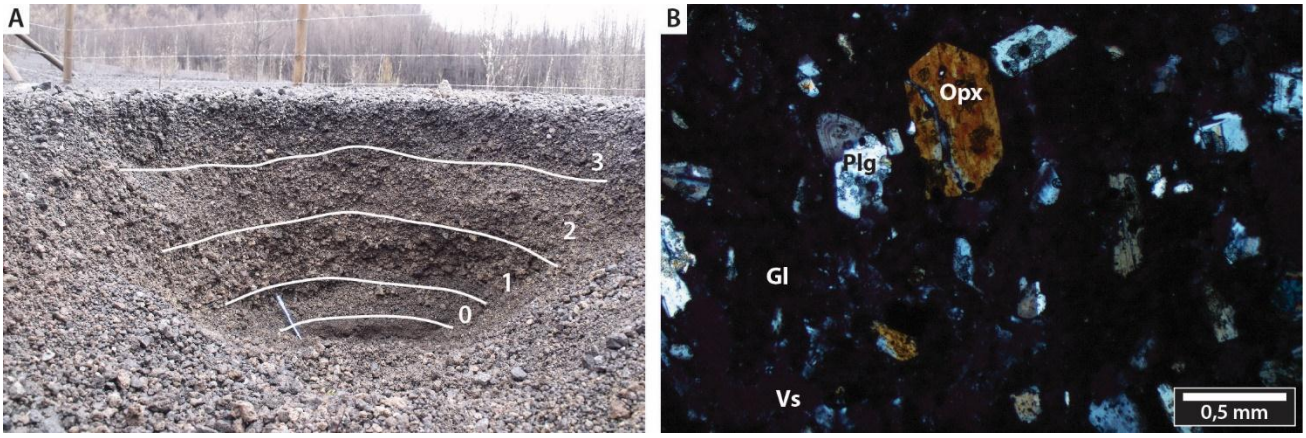


Figure 1. A: Field photograph ca 6 km NE from the vent, showing the 4 subunits identified in the fallout deposit. B: Microphotograph of a pumice fragment showing the phenocryst assemblage.

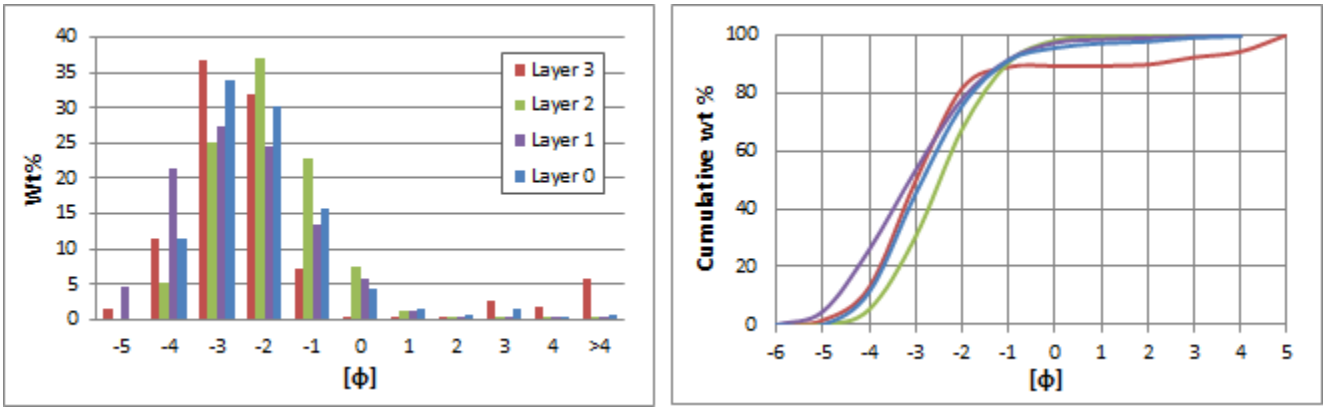


Figure 2. Histograms and cumulative curves for fallout subunit deposits at ca. 6 km to the NE from the volcano.

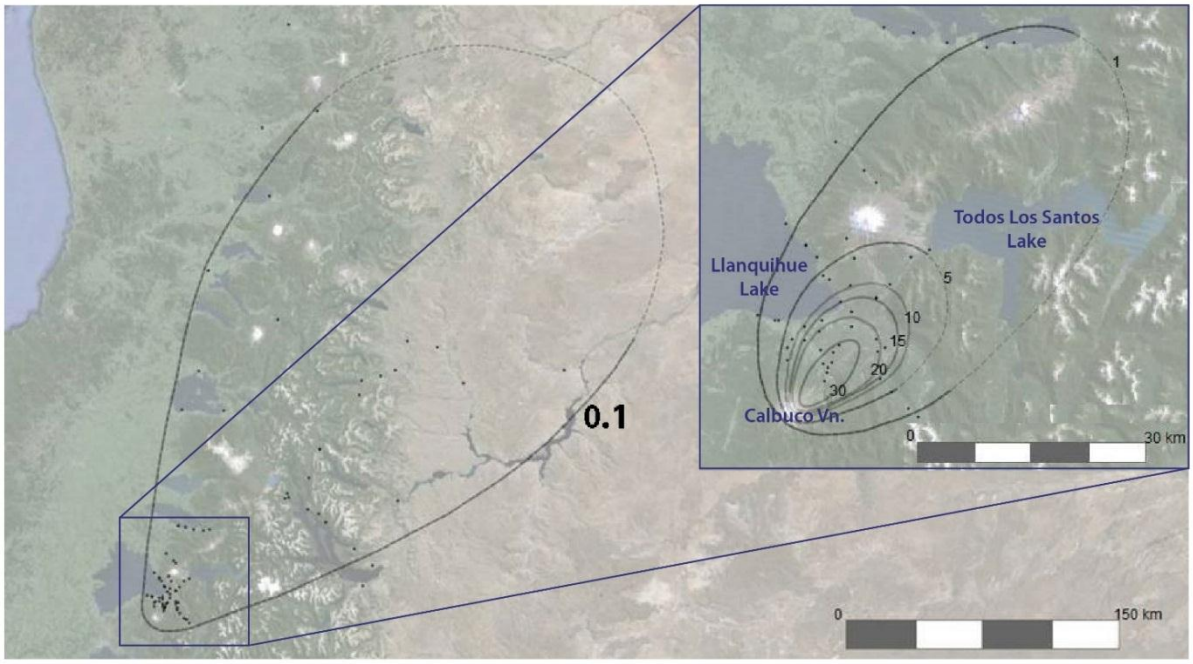


Figure 3. Isopachs of the 22-23 April fallout deposits distributed to the NE of Calbuco volcano.