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## SHORT NOTE

# August-September 2003 small vulcanian eruption at the Nevados de Chillán Volcanic Complex (36°50'S), Southern Andes (Chile)

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## ABSTRACT

During the winter months of August-September 2003 a small (VEI=0-1) eruption took place at the 9 km long fissure-like Nevados de Chillán Volcanic Complex (36°50'S), that includes Nuevo (formed between 1906 and 1945) and Arrau (formed in the 1973-1986 period) volcanoes. Only the local inhabitants and tourists of the ski resort located at the foothills noted the eruption. From August 29 to September 4, 2003, low-magnitude explosive events occurred and brown-greyish to white gas and ash columns reached up to 400 to 500 m above the crater, rising at periods that lasted for 20 to 25 minutes. After the first week, explosions became more sporadic and occurred at two-three day intervals. Strong prevailing winds from the north dispersed the low-altitude plume to the SSE until the eruption finally stopped by the middle of September. A new compound crater is now present in the saddle between Nuevo and Arrau volcanoes. This 64 m fissure-like double crater is surrounded by an area of intense fumaroles near to Nuevo volcano suggesting the renewal of activity in the complex.

*Key words: 2003 eruption, Low VEI, Fissure, Nevados de Chillán.*

## RESUMEN

**Pequeña erupción vulcaniana de agosto-septiembre en el Complejo Volcánico Nevados de Chillán (36°50'S), Andes del sur (Chile).** Durante los meses invernales de agosto y septiembre de 2003 ocurrió una pequeña erupción (IEV=0-1) en la fisura de 9 km de largo del Complejo Volcánico Nevados de Chillán (36°50'S), que incluye a los volcanes Nuevo (formado entre 1906 y 1945) y Arrau (formado entre 1973 y 1986). La erupción fue advertida únicamente por los lugareños y los visitantes del centro invernal situado a los pies del volcán. La semana del 20 al 27 de agosto 2003 se produjeron eventos explosivos de baja magnitud con columnas de gas y ceniza de color pardo-grisáceo y blanco que alcanzaron alturas de 400 a 500 m con períodos de 20 a 25 minutos. Después de la primera semana las explosiones se hicieron más esporádicas ocurriendo a intervalos de 2 a 3 días. Los fuertes vientos predominantes del norte dispersaron la baja columna eruptiva hacia el SSE hasta el final de la erupción a mediados de septiembre. Como resultado se formó un nuevo cráter compuesto en el portezuelo entre los jóvenes volcanes Nuevo y Arrau. El nuevo doble cráter fisural está rodeado por un sector de intensas fumarolas cercano al volcán Nuevo, sugiriendo la reactivación de la actividad en el complejo.

*Palabras claves: Erupción 2003, Bajo IEV, Fisura, Nevados de Chillán.*

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## INTRODUCTION

During the August-September 2003 period, a small eruption occurred at the Nevados de Chillán volcanic complex (36°50'S) in the central part of the southern Andes (Fig.1). Due to the low magnitude of this event and the absence of any monitoring system the eruption was only noted by the local inhabitants and tourists of the ski resort located at the foothills of the western flank of the volcanic

complex. In fact, French visitors provided the authors with the first pictures of an eruption plume, observed in September, allowing recognition of the possible source area. In January 2004, the authors climbed to the craters and a new vent was found. The accounts of the witnesses together with our field reconnaissance three months later, enable us to propose an eruption chronology of events.

## GEOLOGIC SETTING

Nevados de Chillán is an elongated N140° volcanic chain formed by a predominantly andesitic subcomplex (Cerro Blanco) and a more silicic one to the southeast (Las Termas Subcomplex). Older lavas and pyroclastic deposits underlie these Upper Pleistocene-Holocene subcomplexes. The volcanic chain is located inside inward facing scarps on the southern and western sides of the complex. These may represent remnants of caldera walls that are likely to be related to Upper Pleistocene ignimbrite eruptions (Moreno and Varela, 1982; Dixon *et al.*, 1999). These latter authors suggested that since 30 ka the two subcomplexes have evolved contemporaneously, but independently, with distinctive magma chemistries.

A profuse effusive activity characterises both subcomplexes and numerous lavas emitted westwards from Cerro Blanco followed the Río

Chillán valley. Similarly, lavas emitted from Las Termas Subcomplex flowed down the Renegado and Shangri-La valleys. On the northern flank of the Cerro Blanco stratovolcano, the Santa Gertrudis cone and lava-flow generated a lahar in 1861 (Petit-Breuilh in Dixon *et al.*, 1999).

Within the Las Termas Subcomplex, an overlapping of postglacial cones and craters, and associated intermediate lavas up to 35 km down the western valleys occurred. Nuevo volcano was formed during the 1906-1945 eruption, on the north-western flank of Chillán volcano, which was constructed on the south-western crater rim of Viejo volcano, the oldest of the summit crater structures. Until the 2003 eruption, Arrau volcano was the youngest structure of the entire complex. It was formed during the 1973-1986 period, and is aligned with Nuevo volcano and Chillán volcano (Fig. 2).

## AUGUST-SEPTEMBER 2003 ERUPTION

### PRE-ERUPTIVE VOLCANIC STRUCTURES AND FUMAROLIC ACTIVITY

The volcanic structures of the area where the 2003 event took place comprise the northern part of the Las Termas Subcomplex. Besides the Santa Gertrudis 1861 eruption, the most recent activity has been concentrated on the area of the present eruption. Two main cones have been formed there since 1906, built on the former Democrático volcano,

that comprises the eroded and largely-buried remnants of a cone (with a 250 m diameter crater) to the north of Chillán volcano, including remarkably extensive lavas (Fig. 1). The Democrático structure was visible in pre-1973 aerial photographs, but is now almost entirely covered by Nuevo and Arrau volcanoes aligned N135° (Fig. 2).

The Nuevo volcano is a ca. 200 m high conical dacite lava dome complex, associated to a lava flow apron, which overlies the northern part of the

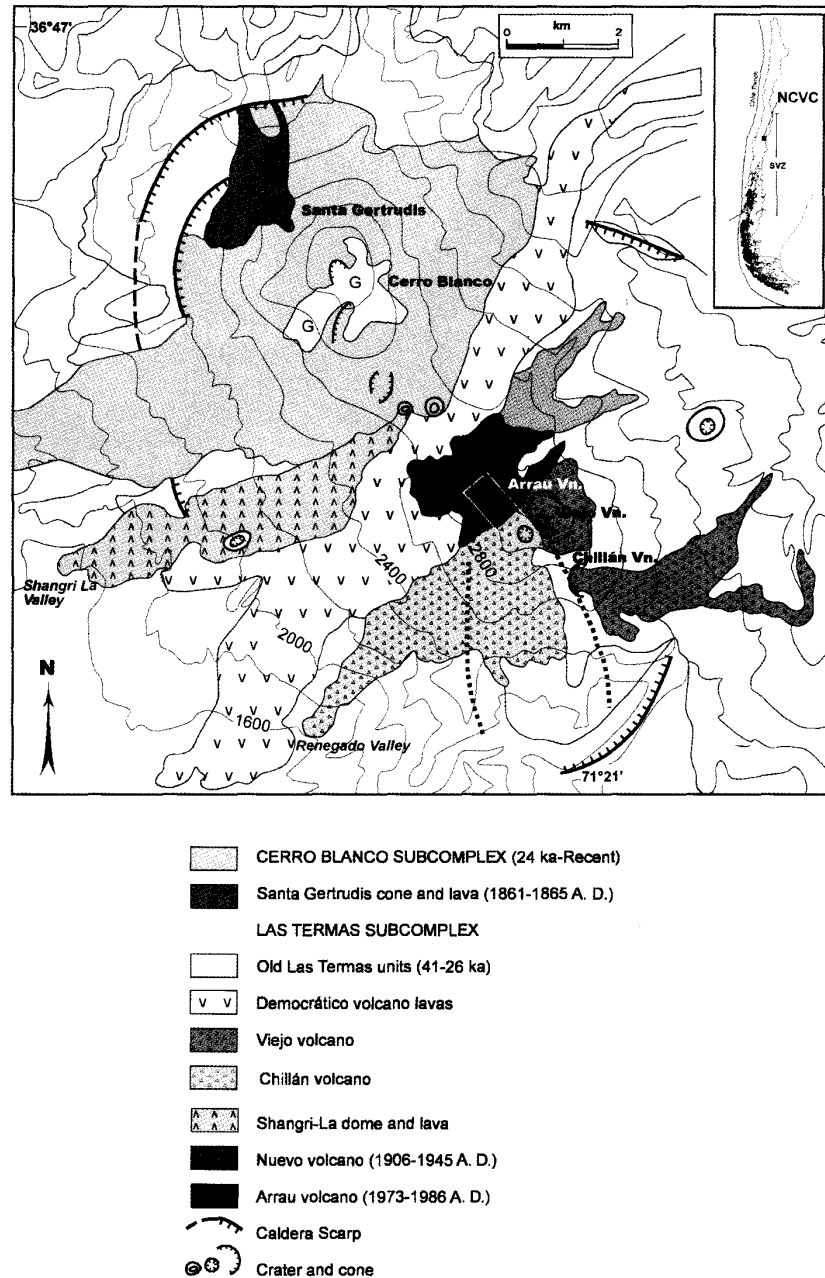


FIG. 1. Geological sketch map of the Nevados de Chillán Volcanic Complex (NCVC, modified from Dixon *et al.*, 1999). The white box shows the active vent area of figure 2. The dashed black lines indicate the tephra dispersion to the south for the August-September 2003 eruption.

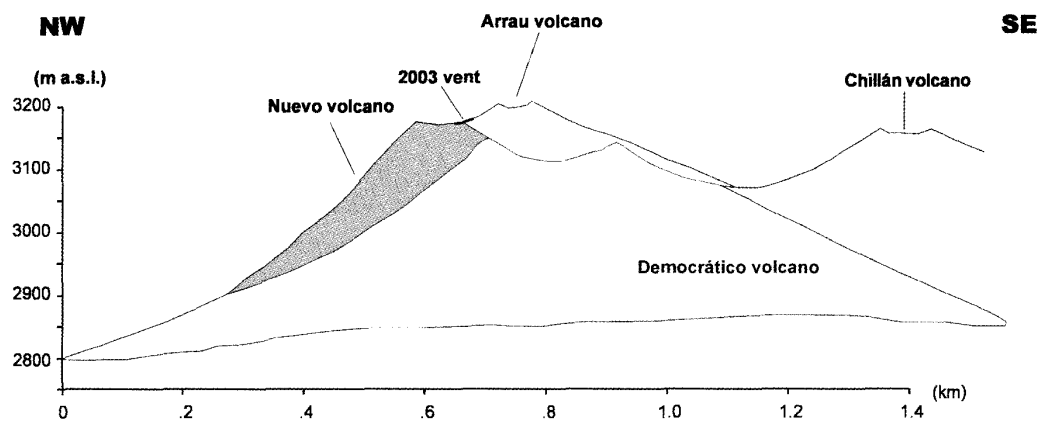
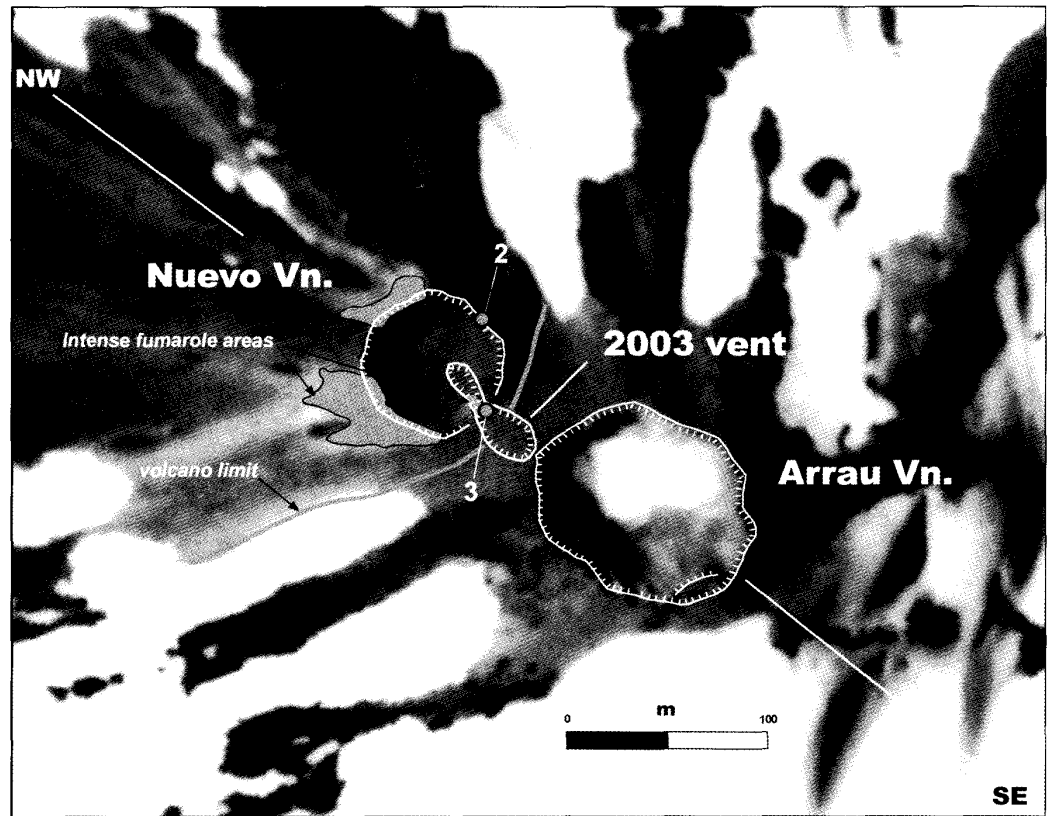


FIG. 2. Detail of a vertical airphotograph showing the active vent area of the August-September 2003 craters (scale bar in meters; north is upwards). Sites 2 and 3 of temperature measurements on January 22, 2004 are also indicated. The section below shows a sketch of the overlying cones and the buried Democrático volcano.

former Democrático volcano. Dome building began in 1906 with sporadic activity extending to 1945, with minor explosive eruptions from the *ca.* 70 m wide nearly flat summit crater, surrounded by intense fumaroles. In January 22, 2004, the water vapour-rich fumaroles (with a weak sulphur odour) all around the crater rim had a temperature of 87.9°C on the eastern side (Table 1). Although no earlier measurements are available, the entire area showed remarkably more intense fumarolic activity in comparison with January 1994, when the authors made their previous observations.

The complex has steep (35–40°) flanks of coulée lavas ('cross' between domes and lava flows) and block-and-ash flow deposits. During the last eruptive cycle (1973–1986), Arrau volcano, a 100–150 m dacite lava cone, was constructed attached to the southeast of Nuevo volcano, completely obliterating Democrático volcano. It was formed between 1973 (Déruelle, 1977) and 1986 reaching its maximum altitude (*ca.* 3,206 m a.s.l.) in 1983 (Naranjo *et al.*, 1994), approximately 20 m higher than Nuevo volcano. Its conic shape is a consequence of coulée lava flows as well as several block-and-ash flow deposits generated by pulses of dome growth and collapse that smoothed the flank surfaces. On its south-west flank, a water vapour fumarole had a temperature of 87.2°C on January 22, 2004 (Table 1). The lava cone has a steep (~35–40°) slope in its upper part and a 120 m wide and 30–40 m deep summit crater.

#### CHARACTERISTICS OF THE 2003 ERUPTION

Eyewitness observations summarised that within the week of August 29 to September 4, 2003, at least four low magnitude (estimated to be  $VEI=0-1$ ) explosive events took place, late in the morning and in the afternoon. Brown-greyish and white gas and ash columns reached up to 400 to 500 m rising from the saddle between the Nuevo and Arrau craters, at periods that lasted for 20 to 25 minutes. After the first week, explosions became more sporadic and occurred at two to three day intervals. Strong prevailing winds from the north dispersed the low altitude plume to the SSE, completely covering the Chillán volcano cone early on September (C. Hubert, written communication, 2004) (Fig. 3). The eruption finally stopped by the middle of that month.

**TABLE 1. TEMPERATURES OF FUMAROLES (JANUARY 22, 2004) NEAR THE 2003 VENT (THERMOCOUPLE THERMOMETER ATKINS MODEL NO. 39658-K; RANGE -80° TO +1,100°C).**

Site (°)	UTM N	UTM W	Temperature (°C ±0.5)
1	288.086	5916.963	87.2
2	288.138	5917.522	87.9
3	288.263	5917.547	57.4

Site 1 is located 1 km to the south of Volcán Nuevo; for sites 2 and 3 see figure 2.

#### ERUPTED MATERIALS

A conspicuous thin (<5 mm) deposit of black ash mantled the remaining snow on January 22, 2004. This could be seen within the crater of the Arrau volcano (Fig. 4). The limits of the deposit are sharply defined on the remaining snow as a 'dirty' grey mantle (Fig. 5). In agreement with the eyewitness observations, the dispersion was directed to the south (N175°), having a width of only 2.2 km (Fig. 1). Within the area of fallout, 2 m long and 5 cm high ridges have formed of damp clusters of 0.5 to 1 cm diameter ash spheres. These structures were probably formed as the ash was remobilised and agglutinated by the snow-melt water. The black damp ridges became larger, with coarser ash, closer to the volcano source. Thickness estimations of the ash mantle are not possible, but it seems that the deposit never exceeded 1 cm thick.

When dry, the tephra has a dark grey colour and a lithic-rich polymodal composition. Grain-size varies from fine ash (*i.e.*, <2 mm diameter) to 4–5 mm particles. The deposit comprises 5–10% lithic-rich coarse ash to fine lapilli of black, grey and reddish aphyric andesite and nearly 60% of fine-medium ash of similar lithic clasts with some quartz and plagioclase broken crystals. In this <1 mm size ash fraction, black glassy particles have broken vesicle surfaces and blocky or plate-like shapes. Juvenile shards with bubble wall morphologies are completely absent. The 30 to 35% remaining fraction comprises light grey fine-grained ash and volcanic dust. Textures and composition are typical of vulcanian-type eruptions and hydrovolcanism (*e.g.*, Sheridan and Wohletz, 1983).



FIG. 3. Eruption plume of the 2003 event (September 1, 0400 PM). The strong wind from the North in September caused near horizontal dispersion (courtesy of Dr. Cadence Hubert).

In addition to particles, the authors assume that toxic gases were emitted as a remarkable amount of dead insects was found among the agglutinated ash.

#### CHARACTERISTICS OF THE NEW EMISSION CENTRE

Both the presence of snow as well as fresh ash on snow within the crater of Arrau volcano, indicates that the emission centre was located to the northwest

of Arrau's crater (Fig. 2). In fact, a new compound crater was found in the saddle region that joins the flanks of the Arrau and Nuevo volcanoes. It is a 64 m long fissure-like double crater, aligned in a N325° direction. The northwestern elliptical crater is 25x14 m in diameters and 10 m deep, while the south-eastern one is 39x28 m and 15 to 20 m deep (Fig. 2). Both craters have funnel shape interiors (Fig. 6). The temperature measured in the water vapour fumarole at the narrowest part between the two craters was 57.4°C (Table 1).

#### DISCUSSION

During the recent effusive activity of the southern Las Termas Subcomplex of the Nevados de Chillán volcano, new relatively small volcanic structures have been built during the XX century. For example, Nuevo volcano (1906-1945) and Arrau volcano (1973-1986) upon the larger and effusive Democrático volcano (Fig. 1) of Upper Holocene age (Dixon *et al.*, 1999). The recent small eruption of August-September 2003 is the first postcessation of the Arrau eruption in 1986. It was centred between both young volcanic craters, closer to the high fumarole flux showed by Nuevo volcano crater rim. The authors have the hypothesis that reactivation

of activity on the Democrático volcano in the northern part of the Las Termas Subcomplex will continue as a new and more extended volcano including Nuevo and Arrau. However, any reactivation of another segment of the 9 km fissure-like Nevados de Chillán Complex cannot be ruled out.

As shown on air photographs and in the field, the location of fumaroles implies that the ground heat-flow is mainly concentrated on the Nuevo rather than Arrau volcano. The latter centre is normally covered by extensive snow patches and shows only few small fumaroles. The active fumarole on the south-eastern part of Nuevo volcano crater



FIG. 4. Photograph taken on January 22, 2004, looking inside Arrau volcano crater. Note the absence of fumaroles and the snow patch covered by dark grey tephra of the 2003 event, indicating the crater quiescence.



FIG. 5. Southwestern flank of Arrau volcano showing the sharp limit of the dark grey ash-fall deposit of the 2003 eruption.



FIG. 6. Eruptive fissure-like double crater aligned in a N325° direction of the 2003 event as seen on January 22, 2004. View to the southeast from the northwestern crater-rim. The smaller crater is in the foreground, beyond the people.

already observed in 1994 by one of the authors (JAN) as well as on the 1998 air photographs, could be the precursory evidence of the 2003 and future

eruption source. The elongated fissure-like crater of the 2003 event located at the former fumarole supports this idea.

## CONCLUSION

The August-September 2003 small vulcanian eruption of Nevados de Chillán volcano has been the first eruption since 1986. The location of the new vent indicates that the activity has migrated towards

Nuevo volcano to the northeast. Systematic measurements of the fumaroles temperature together with microseismic monitoring would help to assess the potential risks of further eruptions.

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