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New insights about the collapsed Lower Miocene Chaco volcano, southern Central Andes, Chile

José Antonio Naranjo*, Victor Villa, Cristián Ramirez
Servicio Nacional de Geología y Minería, Av. Santa María 0104, Providencia, Santiago.

**Email: jose.naranjo@sernageomin.cl*

Abstract: The forms and morpho-stratigraphic features generated by the Lower Miocene Chaco Volcano collapse make it a unique case in the Andes at these latitudes. The detailed study of stratigraphy, lithofacies, volcanic structures and morphological features allows reinterpreting the volcano geology. This volcano was affected by a SW directed sector-collapse during the Miocene. An ice-cap with sin-glacial explosive activity was accumulated into the avalanche caldera, from where a broad glacial-tongue was extended over the north flank of the volcano. This constitutes one of the first evidences of Miocene glaciations in the southern part of the central Andes volcanic zone.

Key words: Chaco volcano, avalanche debris deposits, Miocene glaciation, glacial landforms and deposits.

1 Introduction

The Chaco Volcano (25°27'S; 69°02'W) is a Lower Miocene (~15 to 17 Ma) compound stratovolcano, located in the western front margin of the Upper Cenozoic volcanic arc. Naranjo and Cornejo (1989) proposed that its original morphology was dramatically transformed due to multiple collapses.

Recently, Naranjo et al. (2013a) have provided new stratigraphic and geochronological data in the vicinity of the volcano. In addition, through Google Earth's satellite images detailed study it has been possible to reinterpret the Chaco volcano geology, as well as to improve the stratigraphic relationships, especially with surrounding Miocene ignimbrites. This abstract has a preliminary scope and ongoing complementary works are necessary in order to fully understand the complex evolution of this Miocene volcano.

2 Volcano geology and geomorphology

The Chaco volcano (5.150 m asl) is a compound stratovolcano with two north-trending twin-cones. Together, these structures have an elliptical base of ~100 km^2 and lacks radial symmetry. Due to the extreme aridity, prevailing in northern Chile since Lower Miocene times (Alpers and Brimhall, 1989), the volcano shows surface morphological features such as blocky lava flows on the northwest and northeast flanks. These flows are lobed, have up to 30 m fronts and some exceed 4 km in length. New evidence provided by Naranjo et al. (2013a) indicates that this volcano overlies one of the oldest (> 18 Ma) Río Frío Ignimbrite units. On the other hand, the youngest (~17.3 Ma) Río Frío Ignimbrite unit, as well as Pajonales ignimbrites (~16.5-16 Ma) interdigitate some products of the volcano. The main aspects of the volcano geology are described as follows.

2.1 Avalanche caldera and deposits

The most remarkable structural feature of Chaco volcano corresponds to a ~4.5 km across avalanching horseshoe theater-caldera, open to the SW, that destroyed both cones. Consequently, vast hydrothermal alteration zones were exposed. These zones have been recognized as a core of intense advanced argillic alteration (with remnants of ancient fumaroles), surrounded by argillic and phyllic alteration with chaotic spatial distribution (Astudillo and Venegas, this congress).

The collapse originated an avalanche deposit emplaced to the west, covering a surface of ~80 km^2 and at least 2.5 km^3 (Naranjo and Cornejo, 1989; Villa and Naranjo, this congress). It is mainly composed of fresh angular lithics and prismatically jointed blocks (PJB) up to tens of meters across, which were disintegrated *in situ*. The matrix consists of a high proportion of block and lapilli-size fresh aspect lava fragments with both clast-supported and fine lapilli matrix-supported domains. Based on velocity estimations for this avalanche (Naranjo and Cornejo, 1989) of ~350 km/h, it is possible to asses that this avalanche deposit was emplaced in less than 5 minutes for a 20 km distance.

A 4.5 x 3 km toreva block was transported at least 3 km to the west, and another 3.5 x 2 block was formed as a collapsing fault of the southern part of the theater. Probably, this toreva block acted as a barrier that drove the main avalanche flow to the west instead to the SW.

It has been locally observed that the surface erosion (pediment) that affected the avalanche deposit also extends over the surrounding Atacama Gravels (the Andean piedmont deposits) and corresponds to the same geomorphological process that probably took place at approximately 10 Ma (Naranjo and Paskoff, 1985).

2.2 Domes and pyroclastic flows

Three exogenous andesitic domes are recognized along the collapsing scarp (Naranjo and Cornejo, 1989). The most prominent one corresponds to a N-S oriented, 1.75 x 0.8 km and up to 170 m thick lava that was emplaced above the proximal toreva block. This dome shows a well defined SE scarp, without frontal talus and developed planar jointing throughout the full thickness and on the dome surface. Similar platy junctions have been interpreted as cooling planar jointing (Mathews, 1952). Partial collapses of this dome originated block and ash flows that were emplaced to the SE foot of Chaco Volcano, above Pajonales Ignimbrite deposits (Fig. 1). These up to 10 m thick deposits include unsorted porphyric lava blocks and coarse ash-to-block size matrix, some of them altered. The largest blocks have metric scale, with PJB and bread crust bombs (BCB) being common among juvenile material (Naranjo et al., 2013a). It is noteworthy that Naranjo and Cornejo (1989) interpreted this clastic deposit as an avalanche deposit. Juvenile BCB and hydrothermally altered lithic bearing pyroclastic flow deposits emplaced to the NW and SW are also associated to the dome growing stage.

2.3 Glacial landforms and deposits

A 3.5 km long and 100 to 350 m deep, U-shape valley was probably the result of glacial erosion of the NW Chaco volcano flank. The morphology of the headwaters of this glacial valley suggests that it was connected and fed by a 12 km^2 main glacier ponded within the avalanche caldera, between 4,700 and 5,000 m asl. To the NE, it was contained by the NE caldera scarp, while to the southeast, it eroded an escarpment against the exogenous dome and the underlying toreva block.

At the foot of the NW glacial valley it is also distinguished a 3.5 km long and 40 m thick moraine arc (Fig. 1). It corresponds to a chaotic clastic deposit with up to 70 cm across fresh lava boulders and blocks in a sand to gravel size matrix.

Pyroclastic flow deposits of the volcano, as well as Pajonales Ignimbrite of 16 Ma, were emplaced between the glacial valley and the moraine arc. It must be noted that Naranjo and Cornejo (1989) misinterpreted the glacial scarps as a narrow avalanche caldera, and the moraine deposit as part of the corresponding avalanche deposit.

3 Discussion

Based on 3D photogeology of restricted areas, Naranjo and Cornejo (1989) interpreted deposits and forms of Chaco volcano as multiple volcanic avalanching processes. However, after the new facies and structure analyses it has been possible to infer that their interpretation was not quite correct. In fact, the comprehensive review of the deposits evidences clear contrasts between actual volcanic avalanche deposits (including megablocks, multiple matrix sizes and lithological domains), compared with the deposits to the north and southeast of Chaco volcano (Naranjo and Cornejo, 1989), which show more homogeneous textures.

This analysis allows to re-interpret the proximal facies of the avalanche where giant toreva-type blocks, acted as a structural barrier that drove the westward emplacement and final distribution of the avalanche deposits.

Moreover, the abundance of altered lithic clasts in pyroclastic flows deposits, sharply contrasts with the absence of these fragment-type in the avalanche deposit that precedes them. Furthermore, it is possible to infer that the presence of an extended ice cap favored the expansion of the profuse hydrothermal alteration zone beneath the glacier, which ultimately provided the altered accessory clasts.

Notably, on the basis of new morpho-stratigraphic framework provided here, the presence of glaciers up to 12 km^2 in Chaco Volcano is constrained between 16 and 17 Ma and is an important feature in the volcano evolution. In recent works, Naranjo et al. (2013a, b) described moraine deposits in Miocene volcanoes elsewhere between 25° to 27°S (i.e. the ~11 Ma De La Pena and the ~16 Ma Puntiagudo de la Isla volcanoes). Thus, it is suggested a substantial period of glaciation in the area, which could manifest itself in several pulses. Furthermore, Wijninga (1996) and Reutter et al. (2012) provided paleobotanic background, that would indicate Neogene glaciations in the Colombian Andes, 2,500 m asl.

4 Conclusions

The forms and morpho-stratigraphic features generated by the Lower Miocene Chaco Volcano collapse make it a unique case in the Andes at these latitudes.

On the basis of a restudy of the stratigraphy, lithofacies, volcanic structures and morphologies of Chaco Volcano, it is concluded that this volcano was affected by only one sector-collapse during the Miocene. Within the avalanche caldera, the main accumulated glacier fed an extensive glacial-tongue to the volcano northern flank. It is also deduced that this volcano developed sin-glacial explosive activity.

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