Geology of the Domuyo geothermal area, Patagonia, Argentina

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Introduction

The Domuyo volcanic complex (DVC) is the highest mountain in Patagonia (4,709 m.a.s.l.) (Fig 1). Previous works considered it as an extinct stratovolcano of Pliocene age, although, since the 80's, the existence of a geothermal reservoir on the western slope of Cerro Domuyo has been suggested based on the occurrence of thermal springs as well as silicic domes and pyroclastic deposits dated between 0.55 and 0.11 My (Fig 2).

These early studies proposed that the thermal springs were fault-controlled and the reservoir was located in a graben bounded by E-W striking normal faults. A recent geochemical study (Chiodini et al., 2015) estimated a temperature of 220°C for the fluids in the reservoir and a thermal energy release of ~ 1.1 GW, ranking as one of the world largest advective heat flux from a continental volcanic center.

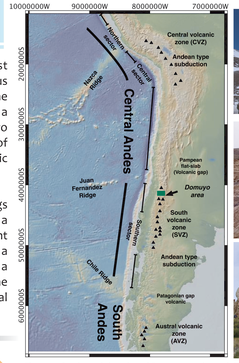


Figure 1. Geodynamic location of Domuyo geothermal area.

Figure 2. a) Domuyo volcano b) "Las Olletas" Thermal spring c) Domuyo pyroclastic flow

Geodynamics and tectonics settings

The DVC belongs to the Andes southern volcanic zone (SVZ: 33°S to 46°S), which has developed in the last 20 Ma years as a result of a slightly dextral oblique subduction of the Nazca plate beneath the South America plate and the upwelling of asthenosphere mantle in the rear-arc region (Fig 1).

The DVC is located at the northern edge of the Cordillera del Viento, a N-S trending anticlinorium uplifted during Cretaceous and Neogene times (Kay et al., 2006) as a result of the main shortening phases that affected this part of the southern Andes. To the west of the Cordillera del Viento the Cura Mallin basin is an Oligo-Miocene tectonic depression mostly filled by volcaniclastic deposits covered by middle to late Miocene ignimbrites and lava flows. East of the Cordillera del Viento, Folguera et al. (2008) documented an extensional phase that produced the formation of a broad basin partially buried by Quaternary Tromén Volcanic Plateau (Fig 3).

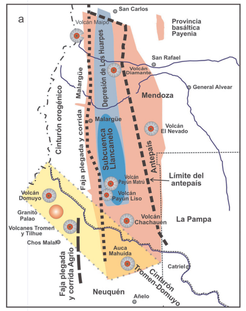


Figure 4. Tromen-Domuyo alignment location (Llambías et al., 2011)

The DVC sites at the NW end of the Tromen-Domuyo volcanic alignment, characterized by several basaltic, andesitic, and rhyolitic volcanic centers transversal to the general N-S structural grain of this part of the Andes.

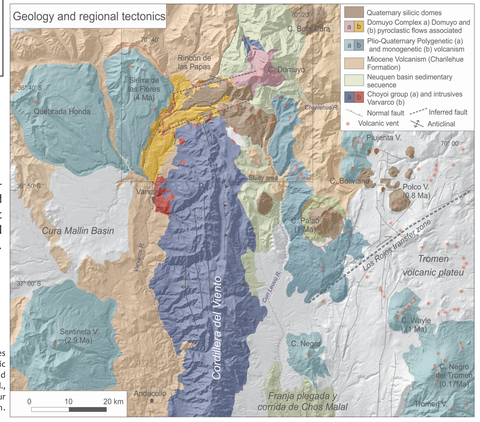
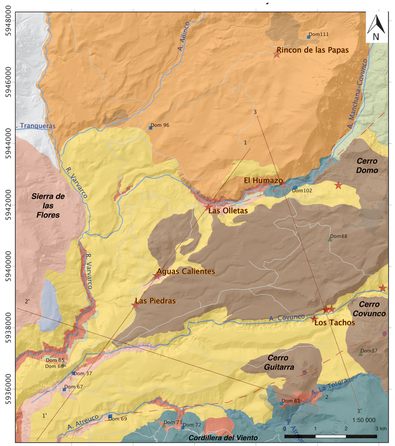


Figure 3. Regional geological map of the Patagonian Andes northern showing the main tectonic settings and the Cenozoic volcanism . The map is based on geological and geochronological information form literature (Burns et al., 2006; Miranda et al., 2006, Folguera et al, 2008) and our interpretation of satellital image and Google Earth.

Study area



Lithology
- Quaternary rhyolitic domes and lavas
- Quaternary Mafic and Intermediate Volcanism
- Domuyo pyroclastic flow
- Pliocene volcanism
- Charlehue formation
- Neuquine sedimentary rocks
- Varvarco instrusive
- Choyoi Group

Interred fault, Geological section, Thermal spring, Alteration, Rivers, Roads

Sampling: Geochronology, Petrography, Geochronology and Petrography, Volcanic vents

Our survey indicate that the DVC is not a stratovolcano, but a dome complex formed by several silicic domes. They overlie an older, Middle Miocene to Pliocene volcanic sequence widely exposed to the southwest and to the north, which in turn cover the Choyoi Paleozoic metamorphic succession with Permian intrusions, and the Mesozoic Neuquen marine sedimentary succession (Plate 1, Fig. 5).

Structural model

The pre-Cenozoic successions are involved in dominantly N-S trending folds and thrust faults later displaced by ENE-WSW striking normal faults with a right lateral component of motion that underlie the DVC but does not affect the Domuyo pyroclastic flow deposit (Map 1; Fig.7: Geological Sections 1, 2, 3).

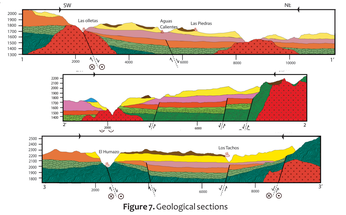


Figure 7. Geological sections

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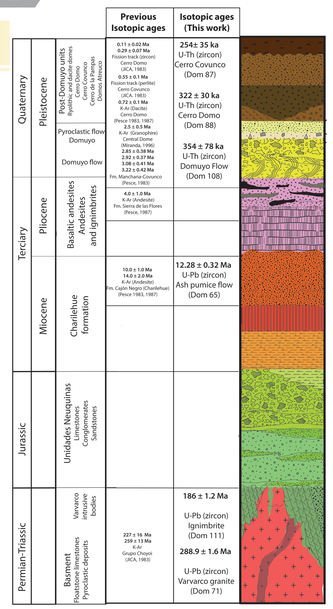


Figure 5. Lithostratigraphic column based on the units identified in the study area. The Domuyo pyroclastic flow is detailed on Fig. 6 owing to its important features.

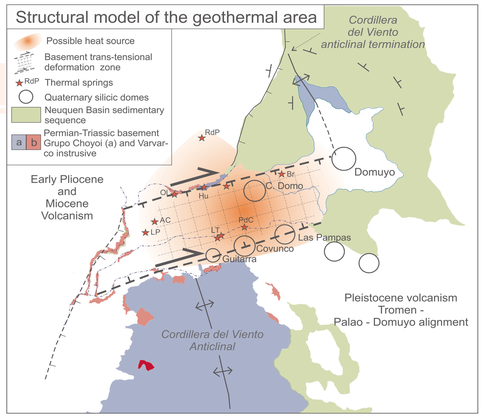
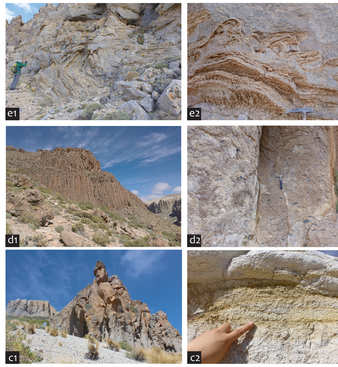


Figure 8. Tectonic framework of the Domuyo geothermal area. The thermal manifestations as well as the youngest silicic domes are located in a transfer right-lateral transtensional transfer zone.

To the northeast of the study area, the rocks of the Choyoi Group and those of the Neuquen basin form a N plunging anticline with an axis in the same direction of the Cordillera del Viento (NNW). This orientation suggests that in the north of the Domuyo could be the northern termination of Cordillera del Viento anticline, but displaced towards the ENE (Fig. 8). Based on this observation, we propose the existence of a shear zone with a right lateral component that offset the fold towards the ENE. The shear zone was possibly formed as a transfer zone during the pre-Oligocene phase of folding and uplift of the Cordillera del Viento, with a possible late Miocene transtensional reactivation.



<<<**Figure 5**. c1,2,3) Charilehue formation: ignimbrites and pumice-and-ash flow.

d1, 2, 3) Pliocene ignimbrites serie. a) Columnar ignimbrite. d2) Superior welded tuff rich in black flammes. d3) Subjacent welded tuff.

e1), e2) Viscous lavas belong to Cerro Domo. e3) Cerro Covunco.

f1) Quaternary mafic volcanism. Cinder cone is covering the Domuyo pyroclastic flow.

>>>**Figure 6**.) Domuyo pyroclastic flow.
a) Block and ash flow.
b) Epiclastic deposits
c) Ignimbritic deposits (Los Bolillos).

The volcanic cycle forming the DVC is distinctly bimodal with the emplacement of massive silicic domes but also less voluminous olivine basalts on its southern slope. The central dome underwent a major collapse that produced a voluminous ash and block flow and associated pyroclastic flows that filled the valley to the southwest up to ~30 km from the source.

This was followed by voluminous effusive activity that formed the silicic domes of Cerro Domo, Cerro Covunco and Cerro de la Pampa. The former two were dated by U-Th on zircons and yielded ages of 254 -35 and 322-20 Ma.

Figure 5. a1) Grupo Choiyoi sedimentary sequences. Sandstones strata dip toward the east. a2) Alteration veins with the same dip direction as the sandstone strata. b1) Neuquen basin units located on the southwestern slope of Cerro Domuyo. b2) Neuquen basin units intruded by the Varvarco granite on the Manchana-Covunco river.

Conceptual geological model

Our new ages for Cerro Domo and Cerro Covunco appear somewhat old for a volcanism associated with a geothermal area of the size of the DVC, for which Holocene silicic volcanism would be expected.
A first possibility is that the silicic volcanism represented by these domes does not correspond with the recentmost magma intrusion, and that magma may have accumulated at shallow level but without reaching the surface. This is likely considering the high viscosity of rhyolite lavas and the lack of Pleistocene extensional structure, which may favor the ascent of these kind of magmas.

Alternatively, the last intrusion in the shallow magma chamber may actually correspond to the emplacement of the Cerro Domo (0.25 Ma), but volume solonger cooling time. The volume of the most recent domes ranges 13 km3, a remarkable value. If we also take into consideration the difficulty of these magmas to reach the the surface one could speculate that the volume of the chamber was much greater, perhaps up to 5 times this volume. The elevation of the basal surface of the emplacement zone of these domes indicates there may be a significant intrusion in depth. It is possible that there is a cooling chamber of many tens of km3 that continues to generate a significant heat flux. Figure 8 illustrates the possible location of the magma chamber in an intermediate position with respect to Cerro Domo and Cerro Covunco. If this model is correct the manifestations with greater component of magmatic fluids should be those of Humazo, Los Tachos and Punta del Camino, which are located closer to the possible heat source, although there may be local factors that cause a dilution.

Conclusions

The geothermal reservoir would be located in the deformed rocks of the Choyoi Group and partially in the sedimentary sequence of the Neuquén Basin. Both groups of rocks have a primary and a secondary permeability produced by faulting and fracturing resulting from the tectonic deformation it was subjected to.

In particular the Domuyo pyroclastic flow represents an impermeable layer which can be an ideal cap rock for geothermal fluids. Excluding the Rincón de las Papas and La Bramadora springs, the other thermal manifestations are located close to the contact between the Domuyo flow deposit and the underlying rocks.

Considering these observations the initial drillings for geothermal purposes should not necessarily be located close to the thermal manifestations, but should be in the eastern half of the study area, in order to approach the heat source. The drilling can be performed from the top surface of the Domuyo pyroclastic flow, guided by the areas of greatest permeability identified by the results of the geophysical studies.

References

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