

The Domuyo Geothermal Area, Neuquén, Argentina

Abel Héctor Pesce

Departamento de Geotermia – SEGEMAR
Buenos Aires 1322, Argentina
apesce@minplan.gob.ar

ABSTRACT

The purpose of the paper is: (1) to review what is known about the Domuyo geothermal area, Neuquén, Argentina, (2) to present a preliminary model of the system, (3) to outline possible future exploratory studies, and (4) to inform about the latest efforts to explore and develop the geothermal resource.

1. Introduction

The Domuyo geothermal area is located in the northwestern sector of Neuquén Province, Argentina, about 550 km (340 mi) of the city of Neuquén, the provincial capital (Fig. 1). It is on the southwestern slopes of Cerro Domuyo, the highest mountain in [Patagonia](#) [elevation: 4709 masl (abt. 15,450 ft)]; Fig. 2. The geothermal area, located at an approximate average elevation of 2000 masl (abt. 6560 ft), presents many surface manifestations, including [fumaroles](#), [hot springs](#) and geysers.

The climate at Domuyo is temperate in the summer, and cold and dry in the winter. The average annual temperature is around 11°C (52°F), the annual rainfall amounts to about 150 mm (6 in).

The first geologic investigations in the area were done by Groeber (1947). Years later, field studies covering about 4700 km² (1800 sq mi) identified and delimited a thermal anomaly at Domuyo (Pesce, 1981). These were followed by detailed investigations centered on that anomaly; i.e., mainly around Cerro Domo (Brousse and Pesce, 1982; Pesce, 1983, 1985, 1987; Pesce and Brousse, 1984; JICA, 1984); Photos 1 and 2. The initial geothermal prefeasibility studies of the area were completed by Pesce (1983) and JICA (1984). The general structural, geochemical and geochronological characteristics of the area were described in the regional report by Muñoz Bravo et al. (1989). More recently, Mas (2010) discussed the geothermal scene for Neuquén.

2. Geology

The Domuyo Volcano is essentially an about 20 km² (7.7 sq mi) volcanic stock intruded where a set of NW-SE and E-W faults intersect. Several monogenic bodies of two magmatic sequences have been recognized that range in age from 2.85 ± 0.38 , 2.92 ± 0.37 , 3.08 ± 0.41 , 3.22 ± 0.42 Ma (Manchana-Covunco Formation) to 0.11 ± 0.02 Ma (small rhyolitic domes) (Pesce, 1983).

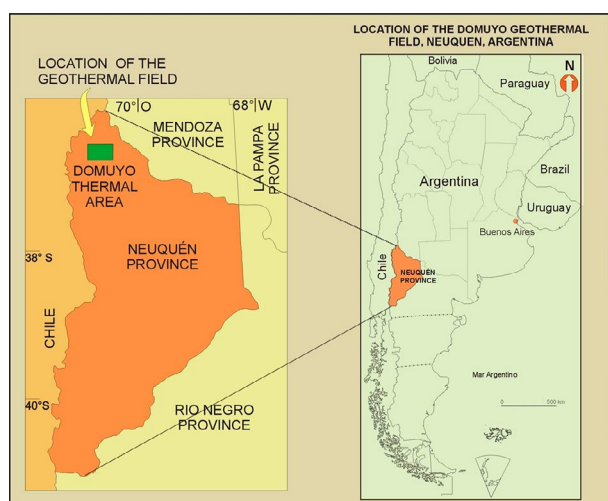


Figure 1. Location of the Domuyo geothermal field, Neuquén, Argentina.

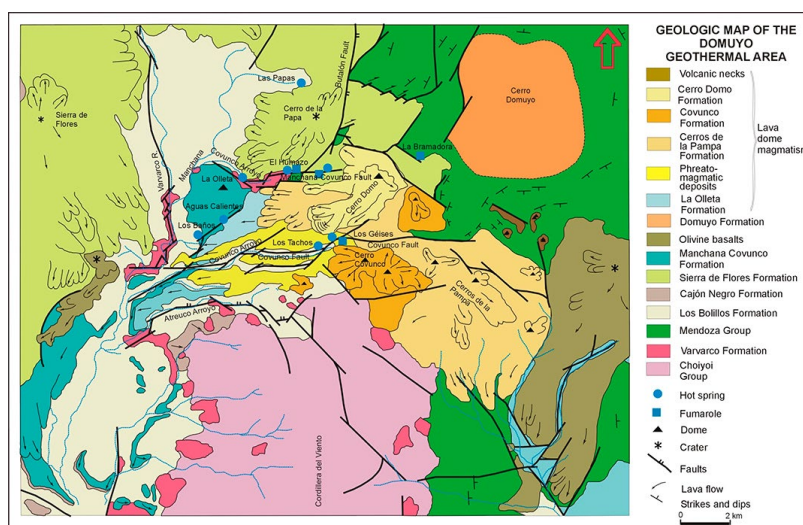


Figure 2. Geologic map of the Domuyo geothermal area. Arroyo: Creek.



Photo 1. Cerro Domo with Domuyo Volcano in the background. Photograph taken from the Covunco Creek looking towards the NE.



Photo 2. Basalts overlying pyroclastic deposits in the foreground; Cerro Covunco and Domuyo Volcano in the background. Photograph looking towards the NE.

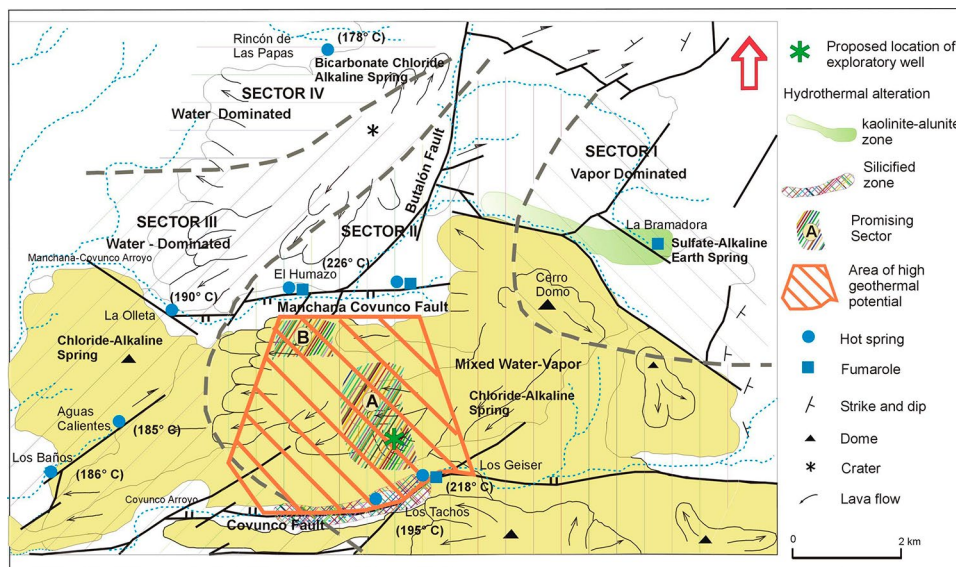


Figure 3. Domuyo geothermal area. Map showing different sectors, spring water type zones, geothermometric temperatures and other features (see legend). Area shown in yellow: lava domes and flows; Arroyo: Creek.

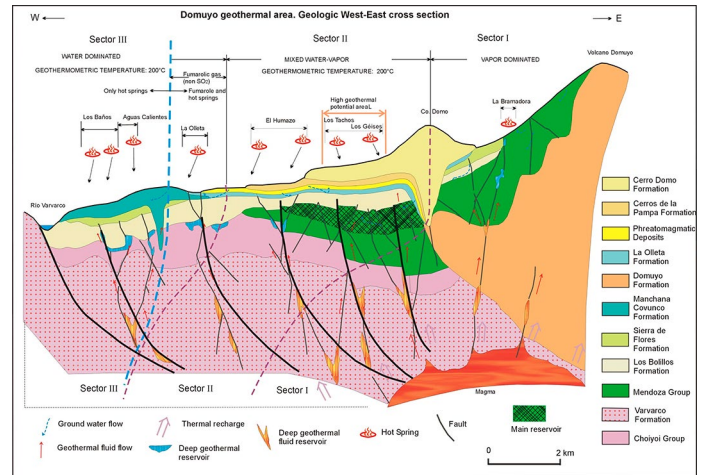


Figure 4. Domuyo geothermal area. Geologic West-East cross section.

Based on field work and analysis of satellite photographs, we do not consider Domuyo to be a stratovolcano as stated in Smithsonian (2013). We consider it to be an inactive volcano in spite of the hydrothermal explosions that occurred in one of the surface manifestation areas (El Humazo; Figs. 2-4) in February 2003 (Mas et al., 2009) and the presence of 0.1 Ma rhyolitic domes.

Geothermal activity at Domuyo is fault-controlled. The geothermal area of potential commercial interest is located in a graben bounded by the E-W Covunco and Manchana-Covunco normal faults (Figs. 2 and 3), and is subdivided into blocks by other faults. Cerro Domo and the surface manifestations are located where the E-W Covunco Fault is displaced by N 30°E and N 35°E faults. The Las Aguas Calientes manifestations are found along the N 35°E faults, while the Olleta thermal spring area is where the E-W Manchana-Covunco Fault is displaced by N 70°W faults.

The geothermal reservoir is inferred to be at about 700 to 800 m (2300-2600 ft) depth, in sedimentary rocks of the pre-Cenozoic Mendoza Group (Fig. 4), which are highly fractured.

3. Exploration Studies

The first Domuyo geothermal exploratory investigations were done by Pesce in 1983; which consisted in geological (structural and volcanological), geochemical and geothermometric studies. In November 1983, the [Japan International Cooperation Agency \(JICA\)](#) explored the area that Pesce had identified as having the highest potential for geothermal development.

The work done by JICA (1983, 1984) included drilling shallow boreholes for heat flow studies, electrical and seismic surveys and isotope analyses of thermal waters. The exploration effort was focused around the Cerro Domo area (i.e., the “study area” located within the graben) where most hot springs and fumaroles are found (Figs. 2 and 3); the presence of that was confirmed by the low Bouguer anomaly and by seismic data.

The JICA (1983) gravimetric studies showed low densities in the eastern part of area depicted in Fig. 3, where the La Brama-dora manifestations and Cerro Domo are located. High densities were observed where the thermal manifestations occur. Finally, towards the West and between these two zones, there is a narrow transitional area elongated in a N-S direction, similar to the strike of the Butalón Fault shown in Fig. 2 and 3 (Pesce, 1983).

3.1 Heat Flow Studies

Eleven 100-m deep temperature gradient holes were drilled in the study area; fluids, cuttings and cores were collected; In seven of them the bottom hole temperatures were above 30°C (86°F); in three they exceeded 50°C (122°F).

Based on measured temperatures and assumed rock thermal conductivities [average value: 11.3×10^{-6} cal/(cm² sec)], the calculated heat output over a 40 km² (15 sq mi) area is about 4.0×10^6 cal/sec (about 16.7 MWt). (JICA, 1984).

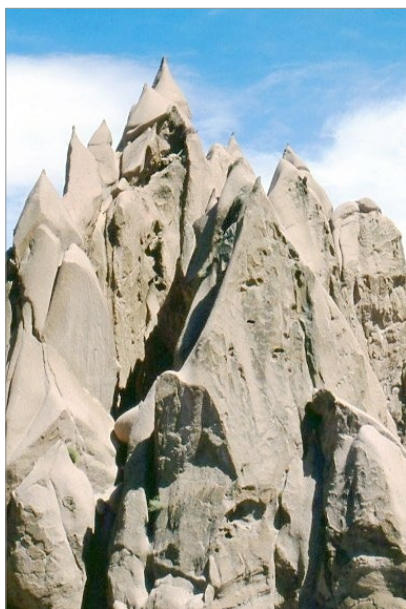


Photo 3. Pyroclastics of the Los Bolillos Formation.

3.2. Electrical and Seismic Studies

Geophysical studies identified a high-resistivity layer in the 200-800 m (660-2600 ft) depth interval, whose upper part gives a strong seismic reflection signal. The layer seems to correspond to the rocks of the Permo-Triassic Choiyoi Group rocks, while the Varvarco Formation granodiorites of similar age are considered to be the area's basement (Fig. 4). Overlying that layer one finds the medium-resistivity Mendoza Group and

above it, the strongly altered, high-resistivity pyroclastics of the Pleistocene Los Bolillos Formation (Figs. 3 and 4; Photo 3), part of the lava dome magmatism.

Shallow, high-resolution reflection seismic surveys done by JICA (1984) show rather continuous reflections west of Cerro Domo at 1000-1500 m (3300-4900 ft) depth, indicating a vertical displacement of the Choiyoi Group rocks by the normal Butalón Fault (Pesce, 1983). In the other parts of the study area, strong reflections were observed at 100-600 m (330-1950 ft) depth, suggesting faults with about 200 m (650 ft) throws. These faults might allow the circulation and upflow of geothermal fluids.

3.3. Geochemistry

Hydrogen and oxygen isotope data on the thermal waters fall on or near the meteoric water line. Their tritium numbers are between 1 and 2 TU (JICA, 1984) suggesting that the source of the thermal waters is precipitation (rain and snow) from high elevations that infiltrate and heat up as they penetrate deep into the system. According to Pesce (1983), most of the fluid recharging the geothermal systems originates from the northwestern flank of the Domuyo Volcano.

A geochemical study of the Los Géises (Photo 4), Los Tachos (Photo 5), El Humazo, La Olleta, Aguas Calientes, Los Baños, Las Papas and La Bramadora thermal manifestations, indicate



Photo 4. Los Géises fumaroles.

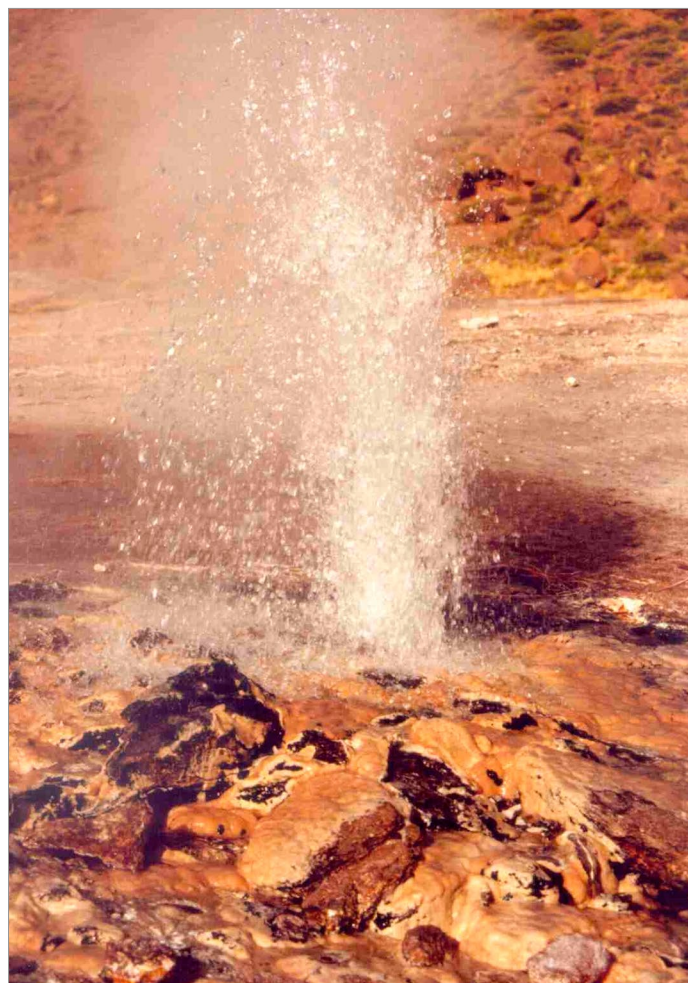


Photo 5. Los Tachos hot spring.

that there are three types of thermal waters at Domuyo. They correspond to four sectors of the geothermal system with different geologic characteristics (Fig. 3); these are:

Sector I. The waters of the La Bramadora fumaroles located in this sector are of sulfate-alkaline earth type, which seem to reach the surface flowing up a deep normal fault. The waters of these manifestations are rich in calcium and sulfates with a SO_4/Cl ratio > 1 .

Sector II. The waters of the thermal springs of this central sector of the study area are of chloride-alkaline type, rich in sodium and chlorides, with a K/Ca ratio > 1 , possible evidence of water mixing. Geothermometry indicates reservoir temperatures of 226, 218 and 195°C (439, 424, 383°F) for the El Humazo, Los Tachos and Los Géises springs, respectively.

Sector III. The waters of the La Olleta, Aguas Calientes and Los Baños hot springs are of chloride-alkaline type, and rich in sodium and chlorides, but with less potassium than those of Sector II. Geothermometric temperatures are about 185°C (365°F).

Sector IV. The thermal waters of the Las Papas springs are of chloride-bicarbonate-alkaline, rich in calcium and bicarbonate; reservoir temperature inferred by geothermometry is 178°C (352°F). Probably the waters are the result of mixing of deep and near-surface fluids. This sector of the system does not seem to present a impermeable caprock.

The chemical characteristics of the four sectors suggest a transition from the La Bramadora steam-dominated system to the central area of the El Humazo, Los Tachos and Los Géises springs, where steam and waters mix, and to the Los Baños, Aguas Calientes and Las Papas water-dominated thermal springs (Pesce, 1983).

3.4. Surface Hydrothermal Alteration

There are two distinct zones of surface hydrothermal alteration at Domuyo. One is observed in the La Bramadora area characterized by acid, medium-to-high temperature (alunite-kaolinite) alteration, which is surrounded by an area a low-to-medium medium temperature (kaolinite) alteration. The other type of alteration found in the Los Tachos and Los Géises area is characterized by a silicified area that extends along the Covunco Fault and seems to be evidence of fossil hydrothermal activity. Extensive argillic alteration (including smectite and kaolinite) was observed around the El Humazo area (Mas et al., 2000).

3.5. Conclusions Reached Based on Exploration Results

3.5.1. Subdivision of the Domuyo Geothermal Area

Taking into account the results of the exploration studies done so far, the Domuyo geothermal field was subdivided into two sectors:

Sector A, extending over an area of 2.5 km² (abt. 620 acres) is north of Los Tachos (Figure 3). Exploratory wells show that the reservoir rocks (Tertiary and Mesozoic fractured, medium-to-high porosity tuffs) should be encountered below about 70 m (20 ft) depth. Electrical and seismic data indicate that the (fractured) basement is at 800-1000 m (2600-3300 ft) depth.

Sector B corresponds to a 0.6 km² (abt. 150 acres) area south of El Humazo (Figure 3). Here, the basement is also thought to be



Photo 6. Cerro Domo shoshonite volcanics.

fractured, but at somewhat shallower depth than in the northern sector; data indicate that the bottom of a low-resistivity unit is below 800 m (250 ft) depth.

3.5.2. Preliminary Geologic Model of the Domuyo Geothermal System

Based on shallow temperature, Hg and CO₂ data, it is thought that the geothermal system is associated with the Pleistocene (100-700 thousand years old) magmatic chamber that was the source of the Cerro Domo shoshonite volcanics (Pesce, 1985); (Photo 6). The chamber is inferred to be centered approximately below La Bramadora surface manifestations, north-east of Cerro Domo (Fig. 3).

According to the model of the Domuyo geothermal system developed by Pesca (1983), magmatic gases and heated infiltrated waters ascend from depth through faults and fractures and mix with colder groundwaters forming a deep 200-300°C (392-572°F) reservoir at 2-3 km (6500-10,000 ft) depth, and a shallower one whose temperature is in the 100-200° C (212-392°F) range.

The reservoir is inferred to be located in the graben of the Cerro Domo area (see Section 2), within the highly fractured Miocene rocks that are overlain by impermeable acid pyroclastics of the Los Bolillos Formation (Fig. 4), which include several tuff and pumiceous layers that form the reservoir caprock. These pyroclastics present high hydrothermal alteration that has changed the volcanic glass into clays. The lateral boundary of the reservoir corresponds to the alteration zone (predominantly silicified) observed in the Tachos y Los Géises areas along the Convunco Fault (Fig. 3).

4. Final Remarks

The next step in exploring the Domuyo geothermal system would involve drilling of a deep, small diameter well in the “high geothermal potential area” (Fig. 3) identified by Pesce (1987). It would be followed by the study/analysis of the fluids, cuttings and cores collected from the well and by downhole geophysical (resistivity, temperature, etc.) measurements. When these investigations are completed, one should have a better understanding of the system, and help decide if further exploratory wells and studies are warranted, and if so, in which area(s) to carry them out.

Initially, in September 2010, the Agencia para la Promoción y Desarrollo de Inversiones del Neuquén Sociedad del Estado Provincial (ADI-NQN S.E.P) asked for bids for the exploration and characterization of the geothermal resources in the Domuyo area. The winner of the lease would have the right to develop it, build power plants, and sell the electricity in the Argentine wholesale market. More recently, the deadline to submit bids was moved to July 10, 2013; see: http://adinqn.gov.ar/pliegos/pliego_geoter_domuyo_02.htm

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