Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

HYDROTHERMAL ALTERATION AT EL HUMAZO GEOTHERMAL AREA, DOMUYO VOLCANO, ARGENTINA

Graciela Raquel Mas[1], Leandro Bengochea[1] & Luis Carlos Mas[2]
gmas@criba.edu.ar lbengo@criba.edu.ar dirhidro@neuquen.gov.ar

[1] Universidad Nacional del Sur- CONICET. San Juan 670. 8000-Bahía Blanca. Argentina
[2] Secretaria de Energía, 8300 Neuquén, Argentina

Keywords: Domuyo field, alteration, zonation

ABSTRACT

The Domuyo volcano is located on the east side of the Andes range in Argentina, where a series of young volcanoes are arranged in NW-SE direction. The Domuyo volcano to the NW is the largest of these volcanoes, which generally decrease in size to the SE. The Domuyo Volcanic Complex consists of late Tertiary intrusives and silicic volcanic rocks. Younger volcanism of intermediate to acidic composition took place during the Quaternary, yielding lava flows of basaltic andesite, andesite, dacite and rhyolite.

Surface manifestations at the geothermal area are most prominent along W-SW slopes of the Domuyo volcano. These include hot springs and fumaroles that commonly occur where young tuff breccias and lava flows directly overlie Mesozoic formations and/or basement rocks. The El Humazo hot spring and fumaroles area is one of the largest areas with surface alteration. Gas geothermometry indicates reservoir fluid temperatures of above 200°C.

The alteration minerals at El Humazo have been studied by means of X-ray diffraction analyses, and optical and scanning electron microscopy. The alteration mineralogy is characterised by the presence of smectite, kaolinite and tridymite, with minor amounts of cristobalite and quartz. In areas surrounding the fumaroles, zeolites such as heulandite and mordenite are also present. These minerals occurred in alteration zones around the geothermal manifestations.

INTRODUCTION

El Humazo means “great smoke” and the area is characterised by abundant steam from the fumaroles and boiling hot springs **(Fig. 1)**. Most of the active and fossil hot spring deposits are located to the southwest of the Domuyo volcano. The Domuyo volcano is located on the eastern side of the Andes Cordillera, a region in which active tectonics and volcanism has occurred since the time of original mountain uplift into the Pleistocene.

Young volcanoes such as Domuyo Volcano, Mt. La Cruzada, Tromen Volcano and Mt. Carrere are arranged in a NW-SE direction in the mountain system of Cordillera del Viento **(Fig. 2)**. These volcanoes are late Tertiary through Quaternary in age. The most voluminous deposits are associated with the Domuyo volcano in the northwestern part of the range.

REGIONAL GEOLOGY

Stratigraphic sequence

- Basement rocks in the region consist of sedimentary and volcanic-pyroclastic rocks of the Permo-Triassic Choyoi Group, and dioritic to granitic plutonic rocks that intruded these older formations.

- Late Mesozoic formations consist of Jurassic and Cretaceous sedimentary and pyroclastic rocks that unconformably overlie the basement.

- Andesitic volcanic activity occurred in the Tertiary, and was followed by related plutonic activity. In late Tertiary, silicic volcanism resulted in lava flows and pyroclastic deposits covering the Mesozoic basement rocks, and large quartz porphyry intrusive bodies were formed in the area around the Domuyo volcano. Silicic volcanics of the Domuyo Volcano Complex can generally be divided into extrusive and intrusive facies. The former consist of alternating beds of rhyolitic tuff, lapilli tuff and tuff breccia, and of lava flows of rhyolite and dacite, distributed on the western slope of the Domuyo volcano. The intrusions form stocks that are centred on the volcano and crop out in an area of approximately 24 km^2. The Domuyo Volcano Complex is middle Miocene to early Pliocene in age.

- In Quaternary time, younger volcanism of intermediate to acidic composition took place in the region and yielded lava flows of basaltic andesite, andesite, dacite and rhyolite. The most recent volcanism in the region is recorded by Domo volcanic rocks that are present along the southwest slope of Mt. Domuyo. They are composed of rhyolitic lava flows and pyroclastic rocks. A radiometric age of 0.72 ± 0.10 Ma has been obtained from one of the early lava flows at Mt. Domo (JICA 1983).

Figure 3 is a geologic map of the El Humazo geothermal area.

Geologic structure

The regional geologic structure is characterised by N-S trending folds that plunge to the north. Near the Domuyo volcano, a dome structure is located along the Domuyo N-S anticline axis. Major fault lineaments occur in N-S (parallel to the fold axes), E-W, and NE-SW or ENE-WSW directions. North-trending faults are regional in scale and are developed in both old and young rocks. In contrast, fault systems with E-W orientations are mostly developed in older rocks. Faults with NW-SE and NE-SW trends appear to form conjugate systems with those of N-S orientation.

The most prominent geothermal manifestations (hot springs and fumaroles) are located to the west and southwest of Domuyo Volcano, and between the Manchana Covunco and Covunco rivers to the west of Cerro Domo. The spring areas include Rincón de las Papas, El Humazo, Las Olletas, La Bramadora, Arroyo Aguas Calientes, Baños del Agua Caliente and Los Tachos **(Fig. 3)**. In all of these areas, except La Bramadora, hot springs and fumaroles occur where beds of tuff breccia and lava flows overlie Mesozoic formations and/or basement rocks. At La Bramadora, steam and fumarolic gases spout through fissures near an intrusive contact at the Domuyo volcano. Travertine deposits and areas with intense clay alteration are associated with these geothermal manifestations.

SURFACE ALTERATION MINERALOGY

The geothermal manifestation of El Humazo is an elongated NE-SW trending zone of obvious surface alteration and active steam and gas emission with numerous steam vents and mud pots. The area is characterized by a high gravity anomaly containing some local gravity lows (JICA, 1983). Although the altered area at El Humazo shows a general NE trend, active hot springs and fumaroles commonly occur at the intersections of two or three fracture systems. **Figure 4** shows a detailed sketch of the El Humazo geothermal area.

The fluids from the hot springs at El Humazo are rich in Na^+ and Cl^-, relatively rich in K^+, and poor in Ca^{++}. They are mixed fluids, consisting mainly of hot water but with large amounts of fumarolic steam and gas. More than 99 mol % of the fumarolic gas is water vapour, and most of remainder is CO_2 gas. Gas thermometry of these fluids indicates that the underlying reservoir fluids temperature may be higher than 200ºC.

In the hot springs-fumaroles area, intense argillic alteration has occurred, and the rock is pervasively altered to a soft siliceous material containing clay, opaline silica, albite and zeolites. Away from the geothermal area, the rocks have not been significantly altered. Primary mafic minerals such as clinopyroxene and orthopyroxene are partially altered to smectite, but still mostly preserved. Secondary minerals are found as open-space fillings in vesicles and along fractures, and as replacement products of plagioclase and mafic phenocrysts and of the groundmass in the volcanic rocks.

The alteration minerals at El Humazo have been studied by X-ray diffraction (XRD), scanning electron microscopy with elemental detection analysis (SEM-EDX), and optical microscopy. The alteration mineralogy in the hot spring area is characterised by the presence of smectite, kaolinite and tridymite, with minor amounts of cristobalite and quartz. Zeolites, such as heulandite, mordenite and stilbite, occur close to active fumaroles. The clay and zeolite minerals are generally arranged in alteration zones around the geothermal area. Strong kaolin alteration along fractures appears to be superimposed on the more pervasive clay and zeolite alteration.

In moderately altered rocks, primary feldspar phenocrysts are partially replaced and the groundmass is converted to a fine-grained mixture of smectite, zeolites and tridymite. Smectite occurs in the altered rocks as a replacement mineral in association with the low-temperature zeolites, giving the rock a bleached appearance, light colour, and soft texture. Petrographically, the smectite appears brownish, non-pleochroic, weakly birefringent, and very fine-grained ($<10\mu m$).

The identification of the three different zeolites is verified by the XRD mineralogy; each zeolite has a unique X-ray pattern. As observed with the SEM, the crystal morphologies are also characteristic of each zeolite. **Figure 5** shows an X-ray diffractogram of a sample containing stilbite, plagioclase, and quartz. Mordenite forms in open cavities as fine radiating needles and in cottony masses of length-fast prisms with low birefringence and parallel extinction. **Figures 6a and 6b** show the EDAX spectrum and a SEM photomicrograph of prismatic mordenite crystals. Heulandite crystals are very thin, platy or elongated, with parallel to slightly inclined extinction. Stilbite occurs as very thin, flat crystals. The EDAX spectrum, and a SEM photograph of flat-topped, triangular-cornered heulandite crystals are shown **in Figures 6c and 6d**. The striations are caused by the parallel growth of thin blades on the (010) face.

Tridymite is the most common silica mineral. It occurs as small twinned platy crystals, as a replacement of the groundmass, or filling fractures and vesicles in the volcanic rocks. Silica mineralisation also occurs as thin crusts of fibrous, radiating chalcedony that lines vesicles and fractures. **Figures 6e and 6f** show the EDAX spectrum and a SEM photomicrograph of chalcedony lining a vesicle.

SUMMARY AND CONCLUSIONS

Three major areas of surface alteration are present in the El Humazo geothermal field. Upstream of the main hot springs-fumaroles zone there is a 100 by 100m area of older argillic alteration. Here, young talus deposits partially cover the altered rocks. Smectite is the dominant clay mineral, and along the margin, cristobalite, tridymite, and zeolites (heulandite and mordenite) are also present.

On the mountain slope closer to El Humazo, strong phyllic-argillic alteration can be observed in a whitish 200m by 50m area. Here, the alteration minerals consist predominantly of sericite, kaolinite and pyrite, with minor amounts of smectite and mixed-layer clay minerals.

The largest alteration anomaly at El Humazo (Fig. 3) consists of travertine in a 500m by 200m area where the travertine deposits are up to 50 m thick. Nearby, altered rocks are typically whitish in colour, with a reddish surface mineralisation near the most active fumaroles and springs. Alteration minerals consist of smectite, kaolinite, tridymite, and the Ca-zeolites, heulandite and mordenite.

Mordenite is a commonly observed alteration mineral in many geothermal areas, and its formation temperature is known to range from about 60º to 160ºC. The precipitation of kaolinite, heulandite and quartz implies temperatures over 100ºC; whereas, cristobalite, tridymite and smectite commonly form below this temperature.

The association of clay and zeolite hydrothermal alteration at El Humazo generally indicates the presence of slightly acidic to neutral fluids at low to intermediate temperatures, corresponding to the outflow at hot springs and fumarolic activity dominated by water vapour.

The altered areas reflect the pervasive argillic (smectite) replacement of the volcanic rock. Silica mineralisation and kaolinite characterises the alteration along fractures. Zeolite minerals occur above the water table, associated with mud pools and fumaroles, possibly reflecting the condensation of gases from deeper boiling zones.

ACKNOWLEDGEMENTS

The authors wish to thank the EPEN (Neuquen Energy Entity) for making available all the existing information and field facilities and to the Universidad Nacional del Sur (Bahía Blanca) for the use of the laboratories and equipment. The comments of Sue Juch Lutz, (University of Utah, USA), who acted as a reviewer, greatly improved the quality of the manuscript.

REFERENCES

JICA; 1983: Argentine Republic. Final Report on the Northern Neuquen Geothermal Development Project. First-Second Phase Survey. Nº 25.

JICA; 1984: Argentine Republic. Final Report on the Northern Neuquen Geothermal Development Project. Third Phase Survey. Nº 23.

ICDD, 1993: Mineral Powder Diffraction Data, International Centre for Diffraction Data.

Tschernich; R.W., 1992: Zeolites of the World. Geoscience Press, Inc., 563 pp.

Fig. 1. General view of El Humazo. For scale, note the presence of two people on the left side of the photograph.

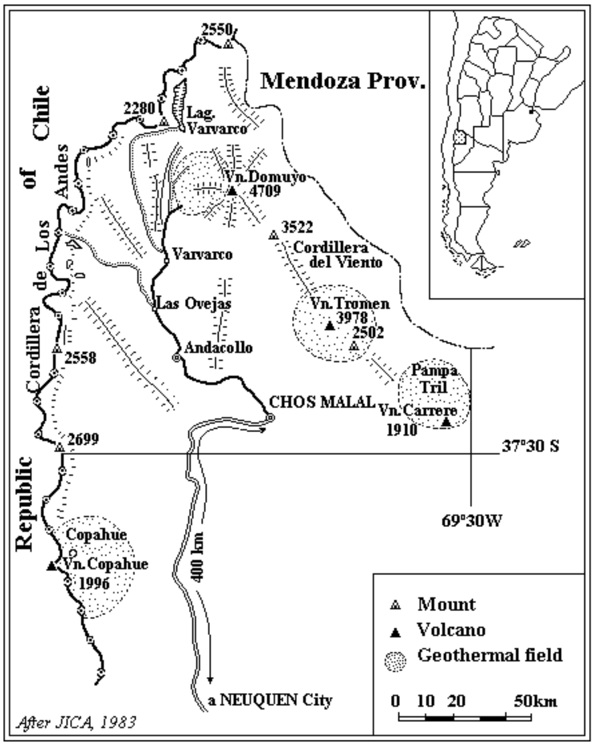


Fig. 2. Location map

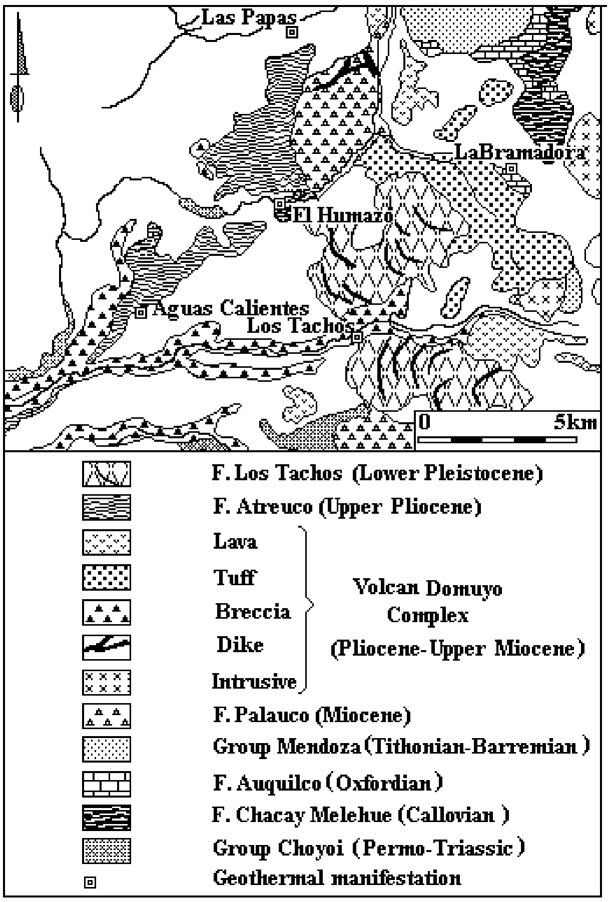


Fig. 3. Geological setting of the area

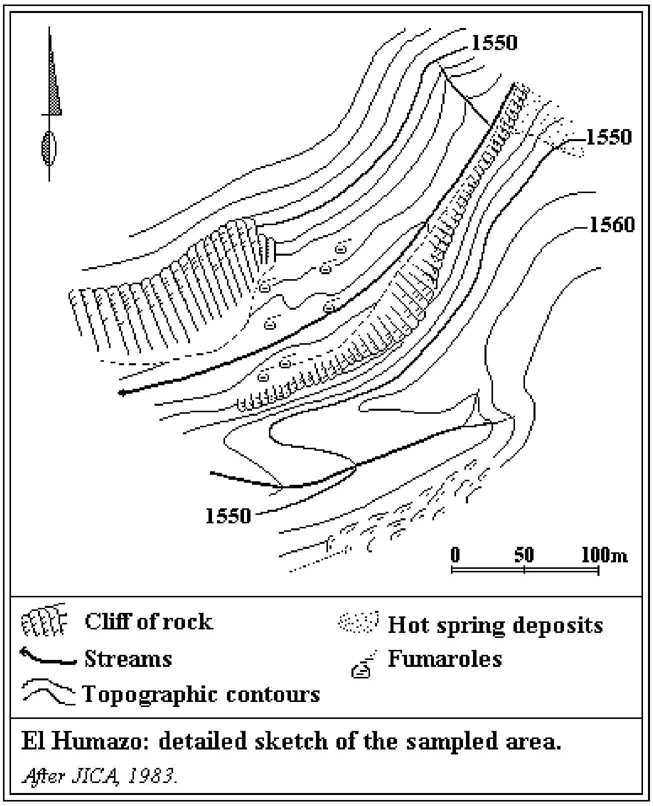


Fig. 4. Schematic drawing of the sample area.

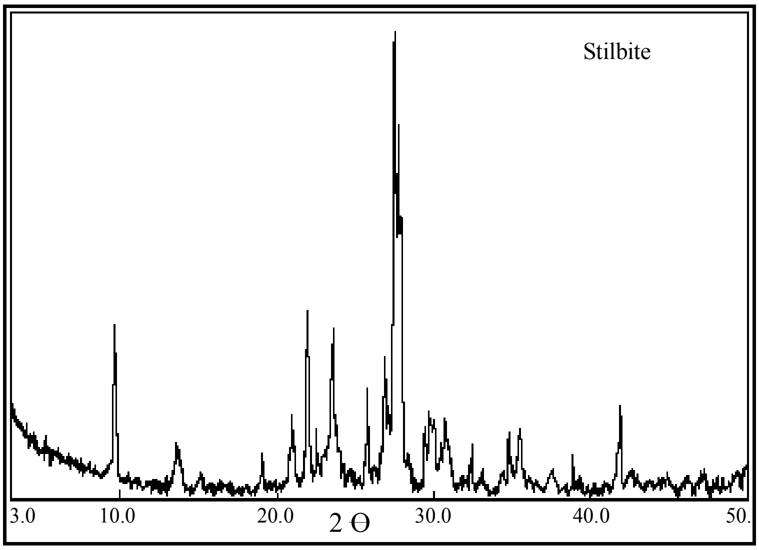
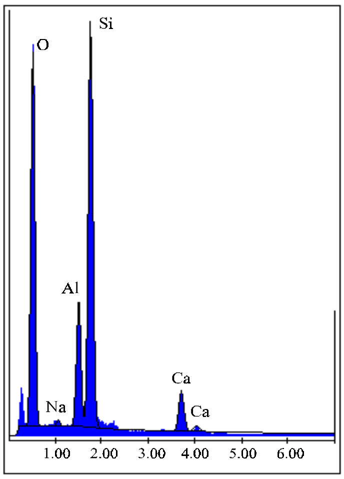


Fig.5: XRD of stilbite from El Humazo.



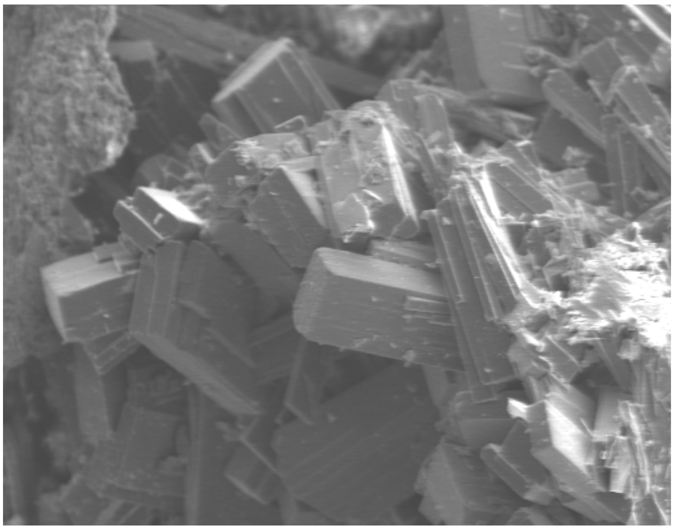
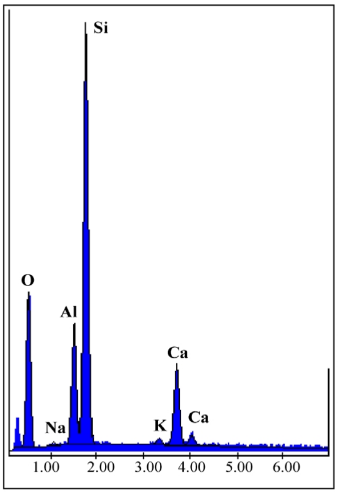


Fig.6a and 6b: EDAX and SEM of Mordenite



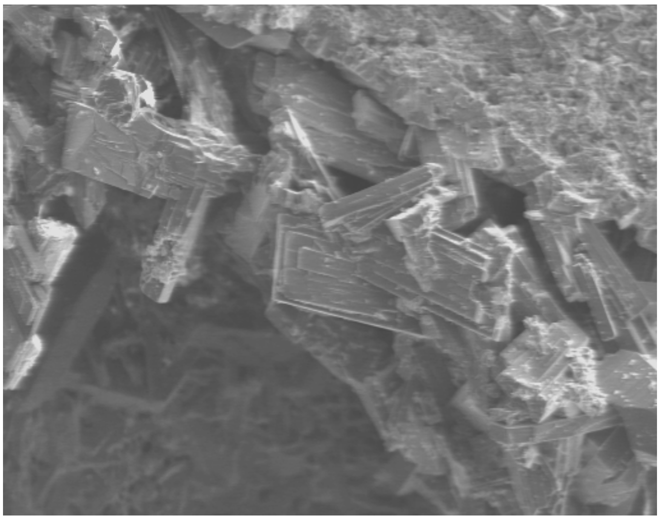
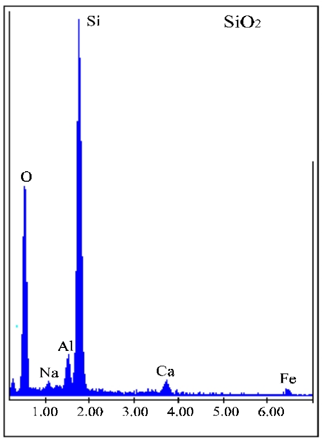


Fig.6c and 6d; EDAX and SEM of heulandite



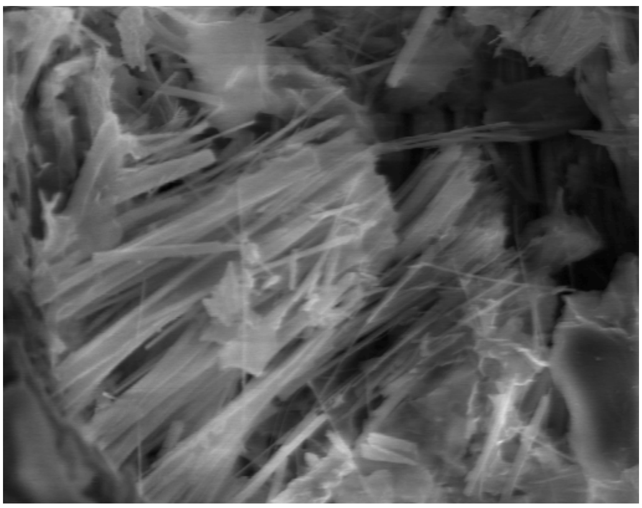


Fig. 6e and 6f: EDAX and SEM of tridymite