GEOTHERMAL EXPLORATION ON PANTELLERIA ISLAND (SICILY CHANNEL) : FIRST RESULTS

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Abstract

Geothermal studies on Pantelleria, a volcanic island located in the median part of the continental rift system between Sicily and Tunisia, date back to the beginning of the sixties. A new geothermal exploration program, involving geological, geophysical, hydrogeological and geochemical studies, promoted by the Sicily Mining Board and sponsored by the European Community, was launched by CESEN in 1990.

The results of the program revealed a very promising zone in the southwestern part of the island, where the main geothermal manifestations are present. Temperature data from exploratory shallow wells and geophysical surveys suggested a water-dominated geothermal reservoir with temperatures around 250 °C at depths of less than 1.5 km. An exploratory well drilled in January 1993 to a depth of 1103 m revealed trachytic lavas alternating with ignimbrites followed by peralkaline microsyenites. Temperature measurements in the well and geochemical data indicated the presence of possible productive zones and subsequent well stimulation led to the production of a two-phase fluid. Further investigations are planned to evaluate the geothermal potential of the field, and to optimize its exploitation.

1. INTRODUCTION

Pantelleria is a volcanic island located in the median part of the continental rift between Sicily and Tunisia. This island is the emerging part of a submarine volcano, 836 m above sea level and about 1200 m below sea level. The surface geothermal evidence consists of fumaroles, moofets and hot springs with temperatures up to 98 °C. These surface manifestations coexist with a volcanism of recent age (around 4000 years) evolved from basalts to acid differentiates (up to rhyolites).

Different volcanic cycles were identified in the island, with pyroclastic and lava flow products that are mainly of the pantelleritic and subordinately trachytic type. The most significant volcanic episodes, dating back to 50-10 ky, have produced two nested calderas that characterize the morphology of Pantelleria.

These calderas, affected by regional and local tectonism as well as by recent volcanic events, have different shapes. The older caldera "La Vecchia", is elliptic while the younger one, named "Cinque Denti" or "Monastero" (Mahood and Hildreth, 1983; Comnitz et al. 1983), is subcircular in shape and originated during the eruption of the "Green Tuff" ignimbrites (45 ky), a widely distributed stratigraphic marker all over the island.

The oldest rocks in the island date back to 300 ky. Six main silicic eruptive cycles have been identified in the last 45-50 ky (Civetta et al., 1989). This probably indicates the presence of a deep and still active magma chamber which gives origin to and feeds the geothermal anomaly.

The main volcanic-tectonic features and eruptive events are represented in Fig. 1. Based on these characteristics, an exploration program was promoted in the 1980-1994 period by the Ente Minerario Siciliano (EMS), Sicily’s Mining Board, in the context of the U.E. program VALOREN, and implemented by CESEN SpA with scientific contributions from the International Institute for Geothermal Research of the Italian National Research Council and from the University of Palermo and the University of Naples.

2. EXPLORATION ACTIVITY

An extensive program of multidisciplinary surveys and investigations was carried out on Pantelleria island, in order to gather all information to be used as a basis for the exploration drilling program.

2.1 Volcanological investigations

Detailed sampling and mineralogical and petrographic studies of the most recent volcanic products revealed that the volcanism derives from a magmatic differentiation process of the most basic terms. This process occurs practically in the same way within each eruptive cycle, with significant similarity for the six recognized cycles and indicates that a primary basaltic magma, tied to the prevailing tensive regional tectonics, is probably located in a deep magma chamber. The magma should be pantelleric in the upper parts of this chamber and trachytic in the deeper parts, due to magmatic differentiation (Civetta et al., 1990).

Eruptions periodically empty the magma chamber lying at a depth of 3-4 km, which is then replenished from depth; its volume has been estimated to be approx. 3.4 km³.

The temperature of the upper part of the magma chamber, as well as that of the host rocks, was estimated at 960 °C by the magnetite-ferromagnetite geothermometer (EMS, 1991).

Specific investigations on subvolcanic xenoliths identified two types of inclusions: a fluid "brine type" inclusion, at high salinity (up to 76% NaCl) trapped at a temperature above 600 °C, and a vapor-rich inclusion, at low salinity (up to 35-45% NaCl), trapped at a temperature around 320-400 °C.

These inclusions indicate that the subvolcanic activity took place under pervasive hydrothermal conditions (De Vivo et al., 1992).

Figure 1. Volcanic and tectonic sketch map of Pantelleria Island (after Mahood and Hildreth, 1983; Civetta et al., 1989).
1) eruptive centers (<6000 yr); 2) faults; 3) Caldera La Vecchia rim; 4) Caldera Cinque Denti rim; 5) thermal spring; 6) exploratory well; A-A' geothermal model profile.
2.2 Geophysical investigation

Geoelectrical, gravimetric and magnetoelluric investigations were carried out, and temperature was measured in the above-mentioned shallow wells. In order to define the geometry and the thermal conditions of the deep buried structures in the island, the Bouguer gravity anomaly distribution on the island distinguishes two different areas (Fig. 3). The first area is characterized by the lowest anomalies and by a smooth pattern of the isolevels, which decrease from 80 to 70 mgal.

The second area, in the remaining part of the island, where the most important volcanological-structural features are located, is characterized by a negative anomaly, coinciding with the central part of the caldera and surrounded by a ring of local positive anomalies.

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2.3 Geophysical investigations

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2.4 Exploratory drilling

The second phase of the exploration program consisted of the drilling of two deep exploratory wells. The drilling targets were the following: to verify whether the deep structure is characterized by a negative anomaly; to determine the geothermal resources; to verify whether commercially interesting resources exist at economic depths.

Drilling depth was estimated considering the possibility of a reservoir at depth. The resistive basement revealed by the electric survey, interpreted in terms of "rigid" rocks with permeability essentially due to fracturing. The above-concluded layer revealed that the basement is practically unfractured and generally corresponds to the ignimbritic units. This could represent the lower permeability cover of a deep hydrothermal system.

Two exploratory boreholes were drilled at depths of approximately 1200 m in the first inside the caldera, at Contrada Serraglia in the SW part of the island, and in the northern part of the island, just outside the caldera in Contrada Ruchi (Fig. 1). Well No. 1 (Fig. 6) crossed three thick trachytic lava sequences separated with two thick ignimbritic units. The first of these ignimbritic units is linked to the formation of the younger caldera "Cinghia Denti" (~50,000 y) and is referred to literature as the "Green Hill."

The second, of a more pantellerite-comendite composition, is probably linked to the formation of the older caldera "La Vecchia."

Further down inside the trachytic lava sequence, from 580 to 700 m, the borehole crossed micro-crystalline dikes and a permeable fractured horizon. Finally, the well crossed a syenitic subvolcanic body to a depth of 1000 m.

The in-hole temperature log indicates a high gradient of about 2°C/100 m between 400 and 580 m, and a lower gradient of about 0.5°C/100 m in the deeper part, 580 m to bottomhole. Considering the fluid saturation curve for a fluid chemically similar to that found in this borehole, we can expect near boiling conditions practically all along the vertical axis of the well.
Figure 4. Resistivity map at the bottom of the cover formation and electrostratigraphical schematic section from geoelectric and magnetotelluric investigations. 1) Isoresistives (ohm·m); 2) exploratory well; 3) M.T. station; 4) V.E.S. station.

Figure 5. Temperature distribution map at sea level. 1) Isotherm; 2) exploratory well; 3) thermometric well; 4) shallow water-well; (A-A') = geothermal model profile.
Figure 6. Schematic stratigraphy and temperature profile of Pantelleria exploratory well 1 (295 m a.s.l.).
1) M. Ghibli and Montagna Grande lavas (trachytic and comenditic); 2) (green tuff); 3) trachytic lavas; 4) trachyphyllite ignimbrites; 5) trachytic lavas intersected by comenditic dykes; 6) production zone; 7) peralkaline microsyenite.

Figure 7. Schematic stratigraphy and temperature profile of Pantelleria exploratory well 2 (205 m a.s.l.).
1) Green Tuff; 2) trachyphyllite lavas; 3) trachyphyllite ignimbrites; 4) alkali-basaltic scoriatic; 5) alkali-basalts; 6) basaltic hyaloclastites crossed by basaltic dykes.

Figure 8. Preliminary geothermal model of Pantelleria Island.
affected by argillation, particularly widespread in the ignimbritic sequences. These conditions are indicative of the circulation of medium to low temperature fluids, and eventual self-sealing processes. Minerals indicative of higher temperatures have formed in deeper layers, and especially on top of the subvolcanic body, where adularia, chlorite and amphibole are present. 

The compact syenitic subvolcanic body appears only slightly altered and basically unaffected by hydrothermal alteration. Within the first 200 m well No. 2 crossed the sainque, but thinner, ignimbritic and trachytic sequence as in well NO. 1 and then passed through a thick basaltic alkaline series down to 650 m. From this depth to bottomhole, it crossed a thick basaltic hyaloclastite sequence (see Fig. 7).

The in-hole temperature logs show lower values than in well NO. 1, with a gradient of about 10°C/100 m and the maximum T value of 126°C at bottomhole. An analysis of the hydrothermal alteration in well NO. 2 reveals wide differences between internal and external caldera zones. The mineral sequence shows a hydrothermal alteration dominated by clay and carbonate minerals, which is in reasonable agreement with the low temperatures recorded. The widespread alteration has led to strong deposition in the paves and fractures of the basaltic sequence. Stimulation tests on well NO. 1, and later tests and measurements, as previously mentioned, identified the presence of a geothermal reservoir in the interval between 600 and 700 in. which includes the permeable brecciated horizons. Steam production from this reservoir is continuous and regular. At a flow rate of 4 tons/hour, although limited in quantity, this represents a positive and encouraging result from the exploration point of view.

The chemical analysis of the water entrained in the vapor collected during the production test suggests that there may be a considerable contribution from the sea to the geothermal reservoir.

CONCLUSIONS

The results of exploration on Pantelleria island have highlighted the wide disparity between the volcanic, thermal and hydrothermal conditions within the caldera structure. Fig. 1 shows a preliminary geothermal model that was reconstructed on the basis of the exploratory surveys and exploratory drilling. The principal source of heat for the geothermal system on Pantelleria seems to be related to the shallow magma chamber feeding the frequent and periodic volcanic activity. and the vapor of subvolcanic bodies surrounding the caldera borders. The data from the two exploratory wells confirm the results of the geophysical and geochemical surveys, and indicate that the positive thermal anomaly extends beyond the "Cinque Denti" caldera, in the SW sector, in correspondence to the system of faults that followed its collapse. Unless new elements emerge to improve the proposed model, the exploitable geothermal reservoir should be sought within the lava and pyroclastic sequences close to the subvolcanic bodies that surround the caldera, as well as in subvolcanic bodies where subvical fractures could exist. The first geothermal deep wells drilled on Pantelleria have decontaminated the potential geothermal interest of the island. The encouraging results achieved so far have led to plans for a second phase of exploration (multidisciplinary surveys and drilling) which will be directed at defining the limits of the geothermal anomaly and assessing the potential of the geothermal system.

REFERENCES


