THERMAL PROSPECTING IN PANTELLERIA ISLAND (SICILY CHANNEL, ITALY)

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Abstract :

A thermal survey was carried out on Pantelleria island during the years 1991 - 1993, as part of a geothermal exploration program. Temperature logs were run in 6 shallow exploratory wells. The thermal data from these wells and from shallow water wells allowed us to reconstruct the temperature distribution at depth. which reveals a positive thermal anomaly in the central-southern part of the island. Two exploratory wells, drilled in 1993 to a depth of about 1200 m in the northern and southern parts **of** the island, confirmed the results of the thermal prospecting, the latter tapping a reservoir with **a** temperature of 250 °C. Heat flow density (HFD) values were obtained in two wells: about 200 mW/m^2 in the north-western part of the island. and around **460** mW/m^2 in the southern part, in correspondence to the maximum of the **thernial** anomaly. These data agree with the trend of the thermal anomaly on the island. and also tit in well with the regional heat flow regime measured in the Sicily Channel. which corresponds to the axis of a continental rift .

1. INTRODUCTION

Pantelleria. a volcanic island located in the Sicily Channel in the median part of the continental rift system between Sicily and Tunisia, is characterized by recent volcanism that. starting from basaltic composition. has shilled towards felsic differentiates, up to peralkaline rhyolites (Civetta *et al.*, 1984, 1988; Mahood and Hildreth. 1986). Apart from the scientific aspect. the island is also of practical interest because of the possible existence of medium-to-high temperature fluids that could be exploited industrially. A geothermal program. promoted by the Sicily Mining Board (EMS) and sponsored by the European Union, was launched by CESEN in 1990, with the scientific collaboration of the International Institute for Geothermal Research (IIRG) of the Italian National Research Council (CNR) (Chierici *et al.*, submitted). Thermal surveys were carried out in 1991-1993 by CESEN in water wells and by IIRG in exploratory wells to evaluate the underground thermal conditions in the island (Squarci **et** *al.*, in press).
In 1991. temperature logs were run in three (Gadir, Bagno dell'Acqua and Nika) of the four wells drilled by CNR in the '60s during the first exploration program on Pantelleria (Barbier, 1969) (Fig. 1). In 1992, during the first phase of the current exploration program, four shallow exploratory wells (PT1, PT2, PT3, PT4) were drilled by CESEN within the **old** caldera, with the aim of better defining the thermal positive anomaly (Chierici *et al.*, submitted). Siting of these wells was based on the information derived from geological, volcanological, geophysical, hydrogeological and geochemical studies. The thermal surveys performed in these wells, together with the above information, led to a first reconstruction of the temperature distribution at sea-level, which indicates that the central-southern zone of the island is the most promising for the recovery of medium-to-high temperature fluids (Squarci *et al.,* in press). In 1993, two deep (about 1200 m) exploratory wells, PPTl and PPT2 (Fig. 1), were drilled by CESEN with the following targets: a) to verify whether the deep temperatures correspond to the values estimated from surface data; b) to obtain information on permeability distribution at depth: c) to verify whether geothermal resources exist at economic depths. The measurements in these two wells (carried out by IIRG-CNR) were made recording both temperature and pressure. The results confinned the hypotheses formulated in the first part of the exploration phase by Squarci *et al.* (in press). 'Temperatures in the range 250-265 °C were recorded in PPTl well between 750 and 1000 m depth, about five months after well completion. Interpretation **of** the data collected in this well, together with information on drilling. indicated the presence of possible productive zones below **500** m depth. with temperatures higher than 220 °C (Grassi *et al.*, 1993). Subsequent well stimulation led to the production of a two-phase mixture of H_2O, NaCl and non-condensable gases (mainly CO_2) (Chierici et al., submitted).

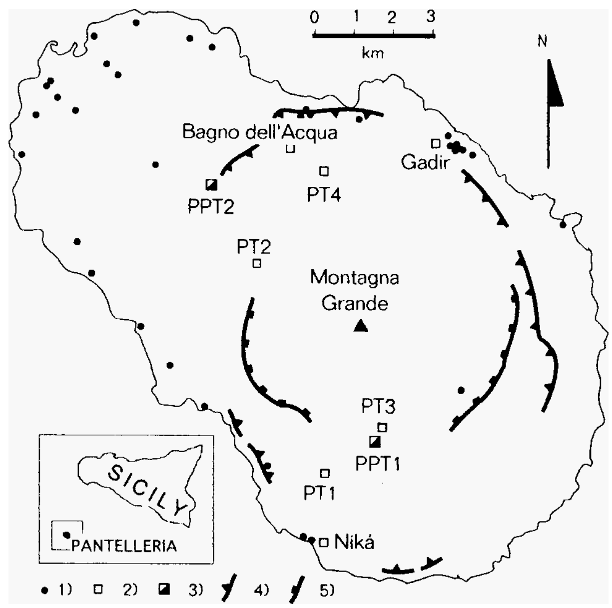

Fig. 1 - Location map of Pantelleria island. 1) water-wells and springs, 2) shallow exploratory wells, 3) deep exploratory wells, **4)** old caldera rim, 5) young caldera rim.

2. SHALLOW EXPLORATORY WELLS

During the first phase of exploration, in 1991, the temperature of the fluid delivered from many water wells producing at sea-level was measured (T range: 18-60 °C; CESEN. 1991). In the same year a thermal survey was carried out by IIRG in the three wells Gadir, Bagno dell'Acqua and Nikà (Fig.1). All three wells are characterized by shallow thermal circulation (with temperatures of ~ 60 °C in the Gadir and Bagno dell'Acqua wells, and ~ 100 °C in Nikà well): underneath, a temperature inversion exists, caused by cold water circulation (Grassi *et al.*, submitted). Because of the inversion, the estimation of temperature at greater depths is not possible in these wells. Based on the results of the geological, volcanological, geophysical, hydrogeological and geochemical studies, and because all the water and exploratory wells are located near the coast, the four shallow exploratory wells drilled by CESEN in 1992 were sited inside the old caldera in order to better define the thermal anomaly. The IIRG carried out the temperature surveys in these wells. The results are summarized below:

- PTI well (Fig. 2): The temperature profiles clearly show an in-hole flow, at least from 140 in (at the contact between the zone altered in clays and the ignimbrites) down to 230-240 m. Because of the in-hole downflow, we cannot obtain the temperature distribution with depth in the formations surrounding the well. The only information attainable is that, in correspondence to the well interval between 200 and 250 m depth, the temperature must he higher than 100 °C.

- PT2 well : During drilling two aquifers were tapped at 40 and 330 m depth, with a water entry of 1 l/s and **5** l/s respectively. The well, drilled to a depth of 400 m, is now accessible down to 210 m. The downflow of water from the shallower aquifer prevents **us** from obtaining any information on temperature distribution at depth.

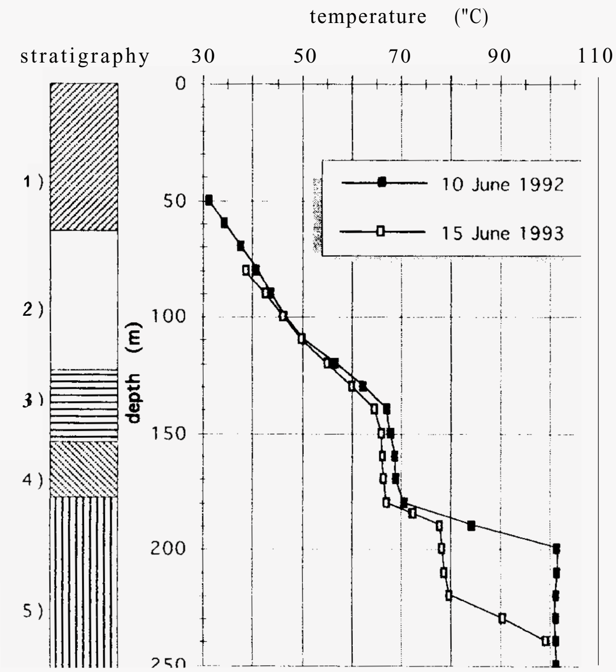

Fig. 2 - PT 1 well (wellhead elevation: +195 m a.s.l.):
1) trachytes-pantellerites; 2) green tuffs; **3)** alteration zone (clays); 4) ignimbrites; 5) pyroclastic deposits.

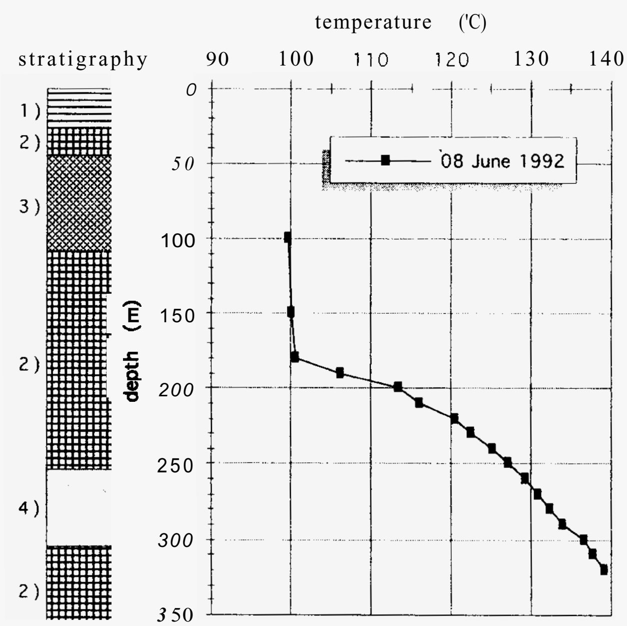

Fig. *3* - PT *3* well (wellhead elevation: +290 m a.s.l.): 1) altered trachytes; 2) grey trachytes; **3)** reddish trachytes; 4) green tuffs.

- PT3 well (Fig.3): During drilling, a loss of circulation occurred between 200 and 220 m depth, without evidence ofwater entry into the well, and production of saturated steam started suddenly when the well crossed the contact between the low permeability "green tuffs" and the underlying trachytic laras. The temperature profile in the well is affected by the boiling of fluid at the water-level and cannot be considered stabilized since it was measured about one month after well completion. **A** slight cooling is still evident in correspondence to the loss of circulation at 200-220 m. However, because of fluid production, the 140 "C recorded at 320 m can be considered as representative of the undisturbed formation temperature.

- PT4 well (Fig. **4):** The temperature logs run in this well indicate the presence of: a) a thermal aquifer with temperatures of about 110 °C between 135 and 160 m depth; b) a temperature inversion below 160 m depth.

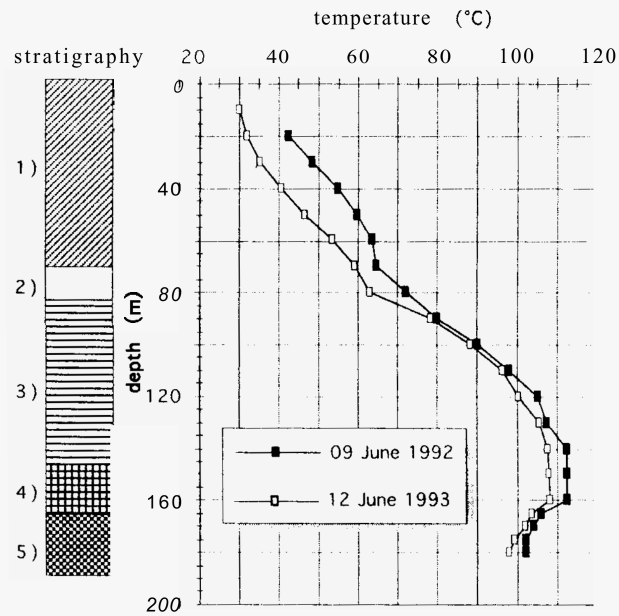

Fig. **4** - PT **4** well (wellhead elevation: +110 m **a.s.l.**): 1) trachytes-pantellerites; 2) green tuffs;3) light grey trachytes (altered);4) dark grey trachytes;5) green Na-rhyolite.

Using the available temperature data from water wells, and shallow exploratory wells. a map of the distribution expected at sea-level was compiled first by Squarci *et al.* (in press), and subsequently updated with the new data gathered in the deep wells PPTl and PPT2 (Chierici ***et al.***, submitted) (Fig. ***5);*** this map reveals a wide area of thennal anomaly in the young caldera, delimited by the 100 "C isotherm. This area could even extend further towards the NW and the south: well PT2 provides no temperature infortnation and well PT1 provides only a lower limit for the temperature at sea-level. The thermal anomaly is particularly marked near well PT3. The fact that thermal aquifers with temperatures between 50 and at least 140 °C cover such a wide area and can even be found at very shallow depths confirmed the hypothesis that the island is very promising for low-to-medium temperature applications.

3. DEEP EXPLORATORY WELLS

During the second phase of exploration two wells. PPTl and PPT2. were drilled by CESEN to about 1200 m depth. The results of the temperature measurements in these two wells are shown in Fig.6.

- PPTl well: The survey was carried out about 5 months after well completion. In the upper part of the well the temperature profile is affected by boiling at the water-level. The temperature log of PT3 well, sited a few tens of meters from PPTl, is reported in the figure for comparison. Boiling conditions elsewhere in the liquid column in the well were hypothesized. To investigate this hypothesis, the saturation curve for a mixture of composition similar to that of the fluid sampled in the well (H_2O, 1% NaCl and 0.2 % CO_2 by weight) was calculated and plotted, together with the saturation curve of pure water and the temperature-pressui-e profile recorded in the well (Fig. 7) (Grassi ***et al.***, 1993).Considering that the fluid coinposition is not uniform all along the column, we cannot exclude this hypothesis. Furthermore. boiling conditions could be reached after complete warm-up of the well.

Interpretation of all the available data indicated the presence of a permeable zone beneath the pantelleritic ignimbrites, and led to well stimulation. The stimulation tests were partially successful, producing a two-phase fluid at a flow-rate of 4 tons/hour (Chierici *et al.*, submitted).

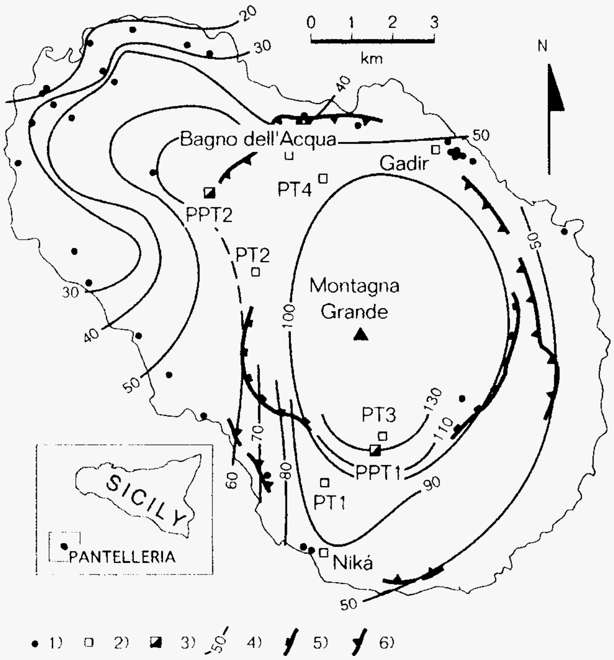

Fig. 5 - Temperature distribution at sea level in Pantelleria island. 1) water-wells and springs. 2) shallow exploratory wells. 3) deep exploratory wells. 4) isotherm (°C). 5) young caldera rim. 6) old caldera rim.

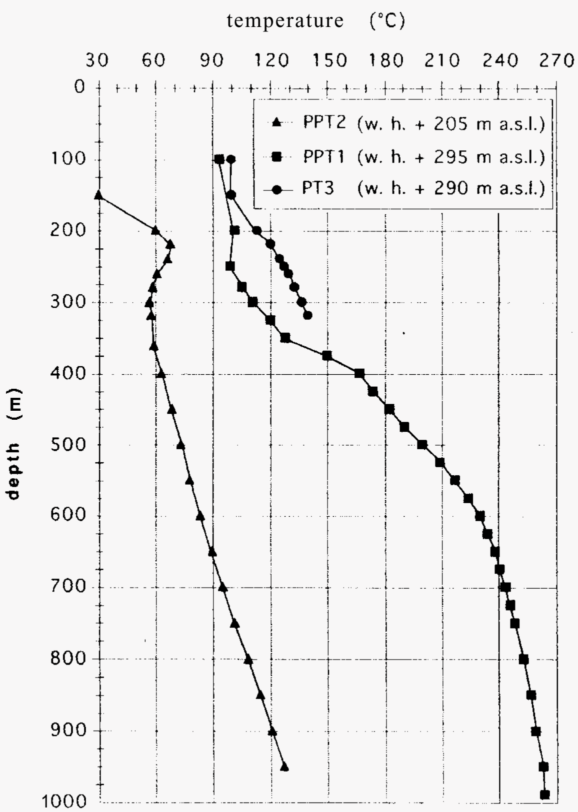

Fig.6 - Temperatures recorded in PPT1 and PPT2 wells about 5 and 3 months. respectively, after the completion. PT3 shallow well data are reported for comparison.

- PPT2 well: Although the temperatures in the well had still not stabilized, it was evident that the deep temperatures in this area are much lower than inside the caldera (Figs. 1 and *6*). The maximum temperature measured in the well is 127 °C at 950 m depth. with a mean thennal gradient of I IS °C/km below the temperature inversion recorded in the upper part of the well. This inversion is probably due to water circulation. with hot water overlying the colder one (Grassi *et al.*, submitted).

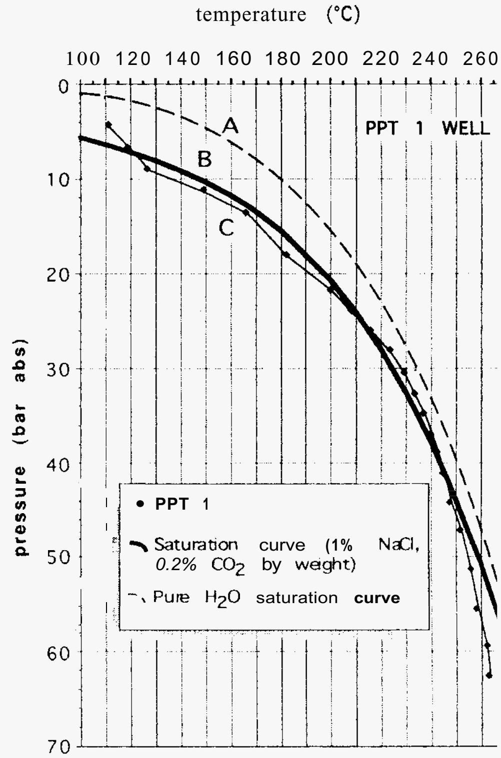

Fig. 7 - Comparison between the saturation curves of pure water (**A**), a fluid mixture of H_2O, 1% NaCI. 0.2% CO_2 by weight (B), and the temperature - pressure profile in the PPT1 well (C).

4. HFD DISTRIBUTION IN THE SICILY CHANNEL

All the available heat flow density (HFD) data gathered on the sea-floor (Della Vedova *et al.*, 1987), and those measured in hydrocarbon exploratory wells on land and off-shore (Western Sicily), indicated the existence of a thermal anomaly that trends along the axis of the continental rift currently active in the Sicily Channel. The maximum of this thermal anomaly seems to coincide with Pantelleria island. The heat flow in the island was estimated in the shallow exploratory well PT3, in the central part of the caldera, using the thermal conductivity value of 1.1 W/mK measured on a sample with analogous lithology collected in PT4 well. **An** HFD value of around 460 mW/m^2 was obtained. The thermal gradient measured in PPT2 well was combined with a thermal conductivity value of 1.55 W/mK (measured on a sample collected at 603 m depth in PPT2 well), to estimate the heat flow at depth. **A** value of roughly 200 mW/m^2 was obtained, which is much lower than that measured in PT3 well. The heat flow data obtained in the two wells agree with the trend of the thermal anomaly existing in the island, and are also compatible with the regional heat flow regime measured in the Sicily Channel (Della Vedova *et al.*, 1987; Squarci *et al.*, in press). These data indicate that the maximum of the thermal anomaly is located within the young caldera in the south-western part of the island.

5. CONCLUSIONS

The thermal survey confirmed that: a) the northem part of the island is characterized by much lower temperatures than the central-southern part. and b) the centre of the thermal anomaly is located within the young caldera, where PPTl well revealed the presence of a possibly exploitable geothermal reservoir. Further shallow exploratory wells should be drilled in order to better define the areal extent of the geothermal anomaly in the eastern part of the caldera.

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