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Chapter 3.6

HDR PROSPECTS IN ITALY AND TUPKEY

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INTRODUCTION

Exploitation of hydrothermal systems is the only commercial way to extract sizable heat quantities from the interior of the earth. The number and location of such systems endowed with high temperature fluids is however limited.

To increase substantially recovery of the immense amount of existing terrestrial heat one has to look for a way to extract it from otherwise tight rocks by creating artificially a fractured underground reservoir and circulating fluids therein to capture some of the available heat (HDR). HDR research and experimentation is underway in several countries around the world and has led to significantly increased knowledge and progress in this field. The concept of HDR has evolved to include artificial stimulation of rocks with latent fractures, adjoining hydrothermal fields or aquifers. Technical challenges to a successful HDR development include: creation of a large underground heat exchanger; control of the fluid flow balance; optimization of heat depletion of the reservoir. HDR systems tapping high temperature rocks at moderate depth have a stronger chance of being economic. Italy and Turkey, as well as Greece are the European countries where this last condition is better fulfilled.

THE ITALIAN GEOTHERMAL SITUATION

Italy is at the centre of the Mediterranean Sea,a region of intense geodynamic activity in rapid geological evoluti-on - corresponding to the collision belt between the African and Eurasian plates. The Mediterranean zone is subdivided in a number of microplates, some of which are under compression, other under distension and other still rotating.

The most evident results of these geodynamic processes in Italy are the orogenic Alpine and Appennine mountain belts, as well as the opening of the Tyrrhenian basin and consequent crustal thinning of the area, with the concurrent upsurge of mantle rocks.

The Tyrrhenian zone, West of Florence and down to Naples and the Eolian islands, in the last 5 million years was the seat of important tensional movements Cwith the formation of rifts and graben) and of strong magmatic activity, evidenced by acidic intrusions in Tuscany and by several volcanic episodes, mainly of alkaline-potassic type (Latium,Campania). The same phenomena originated the volcanic island of Pantelleria, South-West of Sicily. This activity is the cause of the large Tyrrhenian heat anomalies, sometimes over tenfold the average terrestrial flow(Fig.l).

From the geothermal aspect, Italy can

thus be divided in 2 main zones:
- the Western (Tyrrhenian) high enthalpy area;
- the Eastern (Adriatic) cold belt. All the high temperature hydrothermal fields are located on the Tyrrhenian side and are used for electricity production,present installed capacity being 785 MW,mostly in Tuscany. Smaller resources have been found in Latium and near Naples.

Geothermal drilling in the Tyrrhenian belt has evidenced the existence of several important thermally anomalous areas: one in Tuscany and Latium, reaching somewhat Southwards of Rome;another located North and West of Naples; the Eolian archipelago; Pantelleria island. In these areas few hydrothermal systems, of limited extent except than in Tuscany, are interspersed in a prevailingly tight sub-surface domain with high temperature gradient, ideal for HDR experimentation.

CONDITIONS AND LOCATIONS FOR AN HDR PROJECT IN ITALY

The site of a possible Italian HDR project should be selected considering several factors including:
- geologic setting of the area;
- underground temperature distribution;
- geomechanical characteristics of the subsurface rocks;
- availability of water for injection operations and loop testing;
- availability of suitable (open or abandoned) high temperature dry wells;
- limited environmental impact.

All factors considered,a top priority HDR zone in Italy is the broad West Tuscany high heat flow area where the main geothermal fields (including giant Larderello) are located and where drilling is going on,with several wells (some of which still open) that have penetrated hot poorly permeable or tight rocks.

Other areas suitable for HDR experimentation include the Latium volcanic belt, the Flegrei caldera near Naples and some volcanic islands (Vulcano, Pantelleria) around Sicily, all seat of previous geothermal drilling which encountered high temperatures at moderate depth in tight formations. Some of these situations are briefly described hereunder.

<u>Larderello area (Tuscany</u>)

The only Italian HDR experimentation site which is known to have been studied, at least in a preliminary way, is the Colla project, a few kilometers South-West of Larderello (Cianelli et al. 1997; Cianelli 1998).

It would have involved stimulation and circulation tests between 4 directional wells Cone of which tight and the others poorly productive) drilled from a single pad. Rocks penetrated between 2000 and 3000 m are Paleozoic metamorphic phyllites, micaschists and gneisses with a temperature up to 390^{0}C. Maximum bottom-hole separation is 2000 m (Fig.2).

The project, originated in 1996, has not yet been carried out.It was to be a joint effort by ENEA, CNR (both scientific public organizations) and ENEL, the national utility, with government and possibly EC financial support.

<u>Latera area (Latium</u>)

West of this water dominated geothermal field with a 20 Mw power plant there is a broad band of tight rocks (metamorphosed Mesozoic limestones with syenitic intrusions instead of the unaltered fractured carbonates of the producing reservoir) where 3 dry wells (Ll,5 and 6) were drilled. These holes have evidenced temperatures of about 300^{0}C at a depth of 2500 m. The area is logistically favourable, with water availability from the nearby Mezzano lake and good infrastructural support from the adjoining Latera facilities (Cappetti et al.1989).

<u>Sabatini area (Latium</u>)

Sabatini well SH 2 was drilled in 1982-3 and is located 2.5 km North of Bracciano lake. This volcanic area is characterized by numerous small craters of Recent to Quaternary age with pyroclastics and lava outcrops and centers of phreatomagmatic activity.It corresponds to a large positive heat flow anomaly and volcano-tectonic collapse feature (Fig.3). Well SF! 2 was drilled to 2499 m, penetrating the following succession:

0-460 m Recent-Quaternary lavas, breccias and pyroclastics
460-1140 m Tertiary-Upper Cretaceous Flysch: prevailing shales with some volcanic intrusions
1140-2499 m Termometamorphic rocks, flysch type in the upper part,carbonaticsulphatic in the remaining section,with trachytic intrusions

Temperature measurements indicate a conductive behaviour, typical of an impermeable section, with maximum values of 290^{0}C at well bottom.

Flegrei caldera (near Naples)

The caldera ,located few kilometer West of NeapIes. was originated 35,000 years ago. A geothermal multi-reservoir field (Mofete) was discovered in volcanic tuffs at the Western margin of the caldera in the Seventies. Producing levels at depths between 550 and 1900 m contain water with temperature ranging from 210 to 340^{0}C. At the center of the caldera, some 6 km East of the Mofete field,4 wells were drilled which penetrated a substantially impermeable very hot volcanic section. One such well is Cigliano lD, deviated from the S.Vito 1 (T.D.3046 m) pad ,with a bottom hole distance of 140Q m Both wells were dry. The Cigliano lD section is as follows (Fig.4):

0-380 m Pumiceous pyroclastics-Quaternary
380-2650 m Tuffs,interbedded lavas and breccias- Quaternary
2650-2802 Metamorphosed tuffs

Extrapolated temperature at 2780 m (vertical depth 2415 m) is over 349^{0}C; a production test confirmed that the formations are tight. Cigliano well is located in an industrial area,less densly inhabited than the Mofete location,and thus with lesser environmental impact.

Vulcano island (Sicily)

The island, part of the Eclian archipelago, is located North of Sicily and is of recent volcanic origin.

Two geothermal wells (one vertical and one directional) were drilled from the same pad in the Eighties,at the respective depths of 2050 m and 1700 m (vertical depth 1578 m). Bottom bole distance is 460 m (Fig.5).

The section (all of Quaternary and Recent age) of the vertical well Is.V.l is as follows:

0-500 m Tuffs and scoriaceous lavas
500-1360 m Compact and brecciated lavas
1360-2050 m Monzogabbro intrusion

A bottom hole temperature of over 419^{0}C was ascertained(compared to 350-400^{0}C of the shallower deviated well). Both wells encountered impermeable rocks.

Pantelleria island (Sicily)

This volcanic island,located within the continental rift system between Sicily and Tunisia,has high underground temperatures and poor permeability as indicated by two shallow wells (maximum temperature 250^{0}C at 1100 m).

THE TURKISH GEOTHERMAL SITUATION

Turkey is located in the Mediterranean sector of the Alpine-Himalayan tectonic belt, which has an important geothermal potential. Geothermal fields are associated with the graben systems of Western Anatolia, widespread volcanism and tectonism of Central and Eastern Anatolia and with the right-lateral and strike-slip North Anatolian fault zone. Thermal and mineral water resources are developed throughout the above mentioned zones.

In Turkey approximately 170 potential geothermal fields and about 1000 hot and mineral springs with temperatures reaching 242^{0}C have been identified (Fig.6). As result of the research and drilling carried out by the General Directorate of Mineral Research and Exploration (MTA) knowledge on temperature and flow rate of the geothermal systems has increased substantially (Batik et al., 2000;Simsek,2001).

As result of the exploration and development activities carried out, a pilot electrical power plant (20.4 MWe) was installed in Denizli-Kizildere field in 1984 and important developments in greenhouse applications and dwelling heating systems (820 MWt) have been realized in Turkey. Since geothermal energy is clean, cheap and renewable, it is expected that in the near future wider applications will develop all around the country (as indicated in the report prepared by the State Planning Organization, SPO-DPT, which includes geothermal activities in Turkey for the period 2001-2005 (Simsek et al. 2000).

Heat flow density anomalies in Turkey exibit relations with the basic geologic and tectonic strucure (Fig.7). Temperature maps helped to assess the regional field (Tezcan and Turgay, 1991). Very high heat flow of up to 150 2 mW/m is typical for the Paleozoic metamorphic rocks of the Menderes massif in the Western part of Turkey. This area is also seat of many boiling and hot water springs, as well as other geothermal manifestations, located especially along graben structures (Fig.6). Some of these resources are already used for electric power production (Denizli-Kizildere field) and for space heating (Izmir-Balgova area). Drilling has evidenced in several locations high temperatures at shallow depth (231^{0}C at 975 m in Aydin-Germencick; 212^{0}C in well KD 16 at 666.5 m in the Kizildere field). In the same field well R-l (T.D.2261 m) has a reservoir temperature of 242^{0}C. Prospecting for HDR projects in Turkey can be carried out, among other target areas, in massifs associated with young volcanic systems located in the high heat flow regions of Western and Central Anatolia.

CONDITIONS AND LOCATIONS FOR AN HDR PROJECT IN TURKEY

The site of a possible Turkish HDR project should be selected considering several factors ,including:

- Geologic setting and geothermal conditions;
- Geophysical surveys data;
- Priority to economical development regions;
- Limited environmental impact. One such suitable area is described hereunder.

Nevsehir-Acigol area (Central Anatolia)

The surroundings of Nevsehir,220 km Southeast of Ankara and 70 km West of Kayseri are considered to be a potentially important HDR target, due to the presence of recent volcanic and tectonic activity thought to be associated with a shallow cooling magma chamber. Acigol caldera, extending for 100 sq.km, is located in this setting,within a regional high heat flow area. Investigations were initiated by MTA (Mineral Research and Exploration General Directorate) in 1976 geologic and volcanologic mapping, followed in

1977-1979 by gravity, magnetic and resistivity surveys (Fig.8). Exploration results show a basement made up of granite and gabbro-diabase to the Southwest and of metamorphites of the Kirsehir Massif to the North and Northeast, thrust over the Oligocene molasse. Neogene sediments are present in the subsided areas. Volcanics include Upper Miocene and Pliocene andesites and obsidians with several lava and ash flows forming a plateau of 5000 sq.km. After formation of the Acigol caldera (late Pliocene) more volcanic activity followed up to 15000 years ago. Resistivity data indicate a depth of 1000-1500 m of the granitic basement within the caldera (Ongur and Erisen 1977;Yildirim 1984).

The continuous volcanic activity since Upper Miocene tintil Recent times, its history, features and rock types extruded, in an area of high heat flow, suggest the existence of a shallow-seated cooling pluton.

In this situation and considering the lithological section involved,one can expect the preset$_1$ce of hot dry rocks with temperature over 200^{0}C, favourable for the development of artificial geothermal systems.

CONCLUSIONS

Italy presents optimal conditions for

carrying out HDR experimentation in view of large scale commercial development in case of technical success of the demonstration phase.

Italy has ongoing geothermal drilling and production operations in Tuscany and Northern Latium and related testing and stimulation activity aimed at increasing reservoir productivity with techniques easily adapted to HDR heat exchanger creation. Additional know-how is generated by the deep exploration and production operations by the oil industry.

Previous widespread geothermal activity has evidenced large areas with very high temperature, low permeability formations at shallow to moderate depth in the central and southern part of West Italy and in several Tyrrhenian Sea islands.

Italy, with its geothermal knowledge of the territory and its considerable technical expertise, is thus in a key position for HDR development. Turkey on its side has the advantage of being the seat of very large heat flow anomalies which correspond, as verified by measurements in several well to high underground temperature at shallow to moderate depth. Exploration is however less advanced than in Italy and high enthalpy fluids production experience limited.

The extension of the geothermically favourable territory and the less stringent (compared to Italy) environmental constraints, such as the one tied to population density,makes Turkey an attractive place for HOP experimentation.

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