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Medium enthalpy geothermal systems in carbonate reservoirs, the Western Sicily example

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ABSTRACT

The multidisciplinary and integrated review of existing data (mainly acquired during oil exploration), specifically reread for geothermal purposes, and the integration with new data acquired in particular key areas, such as the Mazara Del Vallo site in the southern part of western Sicily, allowed us to better understand this -regional scale- medium-enthalpy geothermal system (with measured temperatures up to 100 °C), to reconstruct the modalities and peculiarities of fluids circulation, and to evaluate the geothermal potentialities of western Sicily. We suggest that these findings could be taken as exemplificative of the behavior of low-to medium enthalpy geothermal systems hosted in carbonate units, that also due to recent technological developments become even more interesting both for direct uses applications and power production.

1. INTRODUCTION

With the exception of volcanic areas, deep carbonate aquifers host probably the most important world geothermal resources. Within more or less karstifed carbonates, widespread fractures generally play an important role both in geothermal fluid flow and storage, making limestones and dolostones really very suitable for exploiting geothermal energy. Carbonate rocks constitute the backbone of Italian Apennines that are to be considered as natural laboratories for the study of these geothermal systems and this is particularly true in the case of western Sicily. From a geothermal point of view western Sicily is a very stimulating area, with the manifestation at surface of several thermal springs, localized areas of moderately high heat flux and thick carbonates units uninterruptedly developing from surface up top great depths.

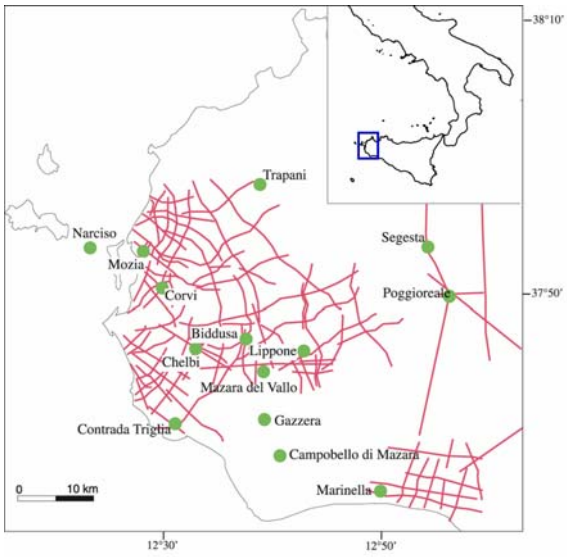


Figure 1: Location map of wells (green circles) and seismic reflection profile grid (magenta lines) acquired by AGIP/ENI (1979–1987).

In this area oil exploration provided new insights for the definition of geometric relationships between tectonic units and structural reconstruction at depth (Catalano et al., 1995; Catalano et al., 1998; Catalano et al., 2002), but also delivered a great amount of data, resulting very suitable for geothermal resource assessment (Fig. 1). We review these data that were

also strongly integrated with geological evidence and geochemical data collected both at surface in correspondence of thermal springs but also at depth in the wells drilled at depth for oil exploration. The multidisciplinary and integrated work here presented allowed us to decipher the functioning of these geothermal systems that in our opinion could be taken as an example for many other similar geothermal systems worldwide.

2. GEOLOGICAL OUTLINE

The western Sicily fold and thrust belt connects central and eastern Sicily to the Late Cenozoic Maghrebian submerged chain developing along the African-European plate boundary. This chain involves a complex architecture of thrust systems resulted from a deformation history active since Oligocene-early Miocene times (e.g. Catalano et al., 1996; Catalano et al. 2002).

Western Sicily is constituted at depth by Mesozoic carbonate platforms (potential geothermal reservoirs) and from their clastic covers, Cretaceous to Miocene in age. From a structural point of view this portion of the chain is characterized in the northern sector by a tectonic stack of units up to 12 km thick and by a southern sector less deformed, but still affected by a certain shortening. Consequently, in the northern portion of western Sicily carbonate platform units and covers extensively crop out being involved in a regional structural high, whereas, to the southwest, these units can be found only in deep wells performed for oil exploration.

3. DISCUSSION

Using the preliminary attempt to evaluate the geothermal potentialities of western Sicily completed by the National Research Council in the frame of the inventories of geothermal resources (Catalano et al., 1982; Fancelli et al, 1991; Fancelli et al., 1994) as a starting point, our approach was to combine the available data with newly acquired geological, geophysical and hydro-geochemical ones, incorporating all information into a 3D geothermal model of south-western Sicily (Fig. 2).

We perform a multidisciplinary and integrated review of the available data, specifically reread for geothermal purposes, these data were also integrated with new data acquired in particular key areas, such as the Mazara Del Vallo site in the southern part of western Sicily. Unfortunately existing data were often collected with the modalities and purposes typical of oil exploration, not always the finest for geothermal exploration as in the case of temperature measurements, that have been adequately corrected.

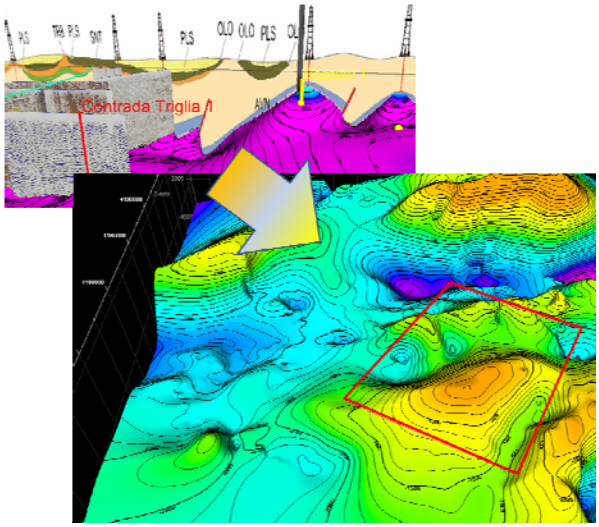


Figure 2: Reconstruction of Mesozoic carbonates, the regional geothermal reservoir as an example of the 3D reconstruction of geometries at depth starting from seismic profiles and geological cross-sections.

This study allowed us to better understand this medium-enthalpy geothermal system (with measured temperatures up to 100°C), to reconstruct the modalities and peculiarities of fluids circulation, and to evaluate the geothermal potentialities of western Sicily.

We identified the main recharge areas of the geothermal system on the higher reliefs in the inner part of western Sicily (e.g. Montagna Grande area).Our review of well data highlighted that away from such carbonatic outcrops the geothermal reservoir deepens towards SW reaching a depth of about 2000 m.b.s.l. in the Mazara del Vallo area (fig. 3). Along the same direction, available measurements pointed out an increase of temperatures from 35-40°C up to 95-100°C (this latter measured in the Contrada Triglia1 well, Mazara del Vallo). The analysis of temperature data measured inside the regional geothermal reservoir allowed us to identify a similar behaviour for temperature variation with depth within the different part of reservoir. Indeed, even if starting from different measured temperatures at the top of carbonate reservoir a gradient of about 10°C km^{-1} was observed in proximal and distal parts of the system -as well as in the intermediate ones- in respect to recharge areas. This feature allowed us to depict the system as a regional scale reservoir with a significant convective flow, identifying the Mazara Del Vallo area as a promising site for geothermal exploitation of this medium-enthalpy resource.

3. CONCLUSIONS

Main conclusions can be summarised as follows:

- •Data collected in W-Sicily allow us to reconstruct the distribution and to verify the lateral continuity at depth of mesozoic carbonates;

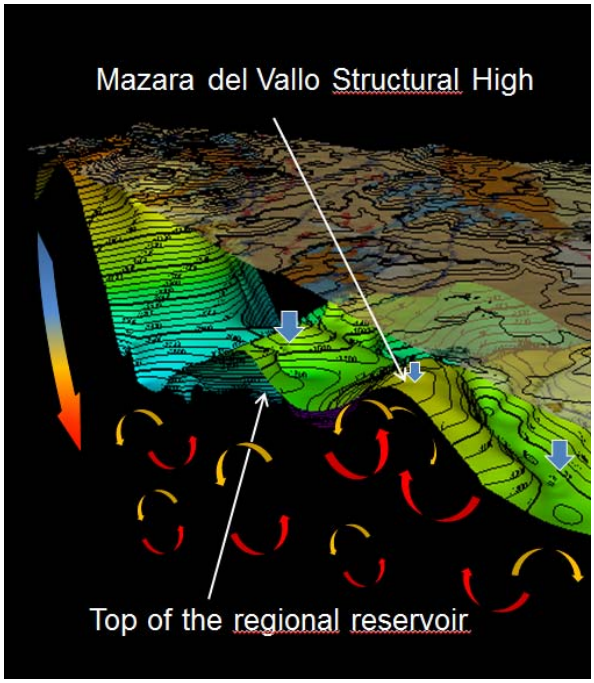


Figure 3:Sketch illustrating the conceptual model for fluid infiltration and circulation at depth.

- Within the carbonate rocks we reconstruct an homogeneous gradient of temperature (about 10°C/km) and a temperature increasing moving away from the carbonate outcrops (30-40 °C) towards distal and confined parts (up to 100 °C) of these hydrogeological complexes;
- The water isotopes of thermal springs allow us to reconstruct the average altitudes of recharge and water residence times in the aquifer suggesting the presence of wide circulation systems
- We identified the main recharge areas of the geothermal system on the higher reliefs on the carbonate outcrops; a possible contribution also from Miocene covers.
- Based on all these information, in the W-Sicily a regional scale reservoir made up of carbonate complexes and hosting geothermal resource of middle enthalpy can be supposed.
- In the Mazara del Vallo area a resource with a temperature of about 100°C can be expected at depths between 1200 and 2000 m b.g.l.

REFERENCES

Catalano, R., Di Stefano, P., and Vitale, F. P.. Structural trends and palaeogeography of the central and western Sicily belt: new insights. Terra Nova, 7, (1995), 189–199.

Catalano R.; Di Stefano P.; Sulli A; and Vitale F.P. Paleogeography and structure of the Central Mediterranean: Sicily and its Offshore area. Tectonophysics. 260, (1996), 291-323.

Catalano, R., Franchino, A., Merlini, S. and Sulli, A. Assetto Strutturale Profondo della Sicilia Occidentale. Atti del 79° Congresso Nazionale – Società Geologica Italiana 1998, (Vol. A,. 257–260).

Catalano, R., Merlini, S., and Sulli, A. (2002). The structure of western Sicily, central Mediterranean. Petroleum Geoscience, 8, 7–18.

Catalano, R., Macaluso, T., Monteleone, S. and Calandra, D. Lineamenti geostrutturali, idrogeologici e geotermici della Sicilia occidentale. Contributo alla conoscenza delle risorse geotermiche del territorio italiano-Progetto finalizzato energetica (1982), 110–120.

Fancelli, R., Monteleone, S., Nuti, S., Pipitone, G., Rini, S. and Taffi, L. Nuove conoscenze idrogeologiche e geotermiche nella Sicilia occidentale. Geologia applicata e idrogeologia, 24, (1991).

Fancelli,R, Nuti,S, Taffi,L, Monteleone,S. and Pipitone,G. Studio idrogeochimico e termico per la valutazione della Sicila occidentale. Inventraio delle Risorse Geotermiche Nazionali. Ministero dell'industriua, del commercio e dell'Artigianato. CNR-Istituto Internazionale per le Ricerche Geotermiche, Pisa (1994).

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