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Thermal regime of the deep carbonate reservoir of the Po Plain (Italy)

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Italy is one of the most important countries in the world with regard to high-medium enthalpy geothermal resources, a large part of which is already extracted at relatively low cost. High temperatures at shallow to medium depth occur within a wide belt, several hundred kilometre long, west of the Apennines mountain chain. This belt, affected by recent lithosphere extension, includes several geothermal fields, which are largely exploited for electricity generation. Between the Alps and Apennines ranges, the deeper aquifer, occurring in carbonate rocks of the Po Plain, can host medium enthalpy fluids, which are exploited for district heating. Such a general picture of the available geothermal resources has been well established through several geophysical investigations and drillings. Nevertheless, additional studies are necessary to evaluate future developments, especially with reference to the deep carbonate aquifer of the Po Plain.

In this paper, we focus on the eastern sector of the plain and try to gain a better understanding of the thermal regime by using synergically geothermal methodologies and geological information. The analysis of the temperatures recorded to about 6 km depth in hydrocarbon wells supplies basic constraints to outline the thermal regime of the sedimentary basin and to investigate the occurrence and importance of hydrothermal processes in the carbonate layer. After correction for drilling disturbance, temperatures were analysed, together with geological information, through an inversion technique based on a laterally constant thermal gradient model. The inferred thermal gradient changes with depth; it is quite low within the carbonate layer, while is larger in the overlying, practically impermeable formations. As the thermal conductivity variation does not justify such a thermal gradient difference, the vertical change can be interpreted as due to convective processes occurring in the carbonate layer, acting as thermal reservoir.

The hydrogeological characteristics hardly permit forced convection in the deep aquifer. Thus, we argue that thermal convection could be the driving mechanism of water flow in the carbonate reservoir. The potential of this mechanism was evaluated by means of the Rayleigh number analysis. A relatively low permeability is required for thermal convection to occur. The carbonate reservoir can be thus envisaged as a hydrothermal convection system of large thickness and extension having a large over-heat ratio. Lateral variation of hydrothermal regime was also tested by using temperature data representing the reservoir thermal conditions. We found that thermal convection is of variable intensity and may more likely occur at an area (Ferrara structural high) where widespread fracturing due to tectonism is expected yielding a local increase in permeability.