SEDHEAT – CARBONATES AS GEOTHERMAL RESERVOIRS

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ABSTRACT

Two properties are required in a geothermal reservoir: temperature and permeability (hydraulic conductivity). Temperature is a function of depth, thermal conductivity, and heat flow. Permeability is a function of rock composition and texture on a micro and macro scale. In general, fine-grained textures have low permeability unless they are competent and can support fracture and/or solution permeability. Medium- to coarse-grained sedimentary textures typically have intrinsic porosity that provides permeability. Highest permeabilities are found in karst limestones, which may also be fractured, and which can allow modest-sized rivers to flow underground where the permeability may approach infinity.

Deep carbonate aquifers are probably the most important thermal water resources outside volcanic areas (Goldscheider et al., 2010). Karst carbonates supply hot springs and wells in many locations, including Budapest (Hungary), Stuttgart (and many other thermal springs and spas in Germany), France, Italy, and the United Kingdom. Hot springs and wells are also associated with carbonate aquifers in Turkey, Jordan, Tunisia, Canada, China and many other countries around the world. In addition to these relatively low-temperature resources, carbonates are also the reservoir rocks for some important power-producing geothermal resources, for example, the 'Tuscan Series' carbonate reservoir rocks at Larderello (northern Italy), and the Upper Jurassic Malm fractured carbonate aquifer in the Alpine Molasse Basin at Unterhaching (southern Germany). During the past decade or so carbonates have been recognized as favorable targets for geothermal exploration in the US (e.g., Morgan, Allis, and coworkers). I suggest that in any geothermal prospect carbonates, if likely to be present at depth, should be considered as potential reservoir rocks.

Carbonates permeability is rarely primary, and highly conductive pathways for hot and cold water are typically widely spaced. These pathways commonly develop through solution of the carbonate and may originate along bedding planes, joints, and tectonic or other fractures. A well drilled at a random location may miss the fracture system. However, fractures tend to be developed and enlarged by solution at the intersections of regional fracture systems, on the crests of anticlines, and, to a lesser extent, along the axes of synclines. Horizontal drilling in the carbonate sequence may improve the probability of intersecting the fracture system. Hydraulic fracturing and acid treatments have been used to improve the connection between wells and natural permeability in carbonate formations.

Bottom-hole temperature data and other thermal information strongly indicate that temperatures above the basement beneath many sedimentary sections in North America and elsewhere are sufficient for geothermal direct use and even power production. The missing parameter is permeability – can the heat be brought to the surface economically with water flow. Carbonates are common sedimentary rocks and often have very high permeability. They may require targeted drill holes, but have the potential to yield very productive geothermal wells.

Figure 1: Crystal Cave, approximately 300 m below the surface, Naica Mine, Chihuahua, Mexico. Example of solution permeability in a carbonate formation. Use people for scale (selenite crystals are up to 11 m long. The cave was pumped dry when this picture was taken; it has now been allowed to return to its natural water-filled state. When pumped dry the temperature was 65^{O}C (150^{O}F) and 100% humidity. Geothermal gradient from surface ~150^{O}C/km.

REFERENCES

Goldscheider et al.: Review: Thermal water resources in carbonate rock aquifers. *Hydrogeology J, 18*, (2010) p. 1303.