AAPG/SPE/SEG HEDBERG CONFERENCE
"ENHANCED GEOTHERMAL SYSTEMS"
MARCH 14-18, 2011 – NAPA, CALIFORNIA

EGS Potential in the Northern Midcontinent of North America

W. Gosnold, R. Lefever, M. Mann, R. Klenner, M. McDonald, and H. Salehfar
University of North Dakota, Grand Forks, ND

We used one-hundred-fifty-four conventional heat flow sites, several hundred bottom hole temperature measurements, lithostratigraphy data, and 368 thermal conductivity measurements made on core samples of Mesozoic and Paleozoic rocks from the Williston Basin to assess the EGS potential of the northern midcontinent of North America. These combined data enabled projection of temperature versus depth profiles with well-constrained thermal conductivity and heat flow parameters. We assumed use of binary power plants at a minimum temperature of 150 °C as a base level for EGS potential. Based on an average surface heat flow of 64.3 ± 19.3 mW m^{-2} (N = 926), a thermal conductivity of 2.6 W m^{-1} K^{-1}, and a mean surface temperature of 7 °C we project the average depth to the 150 °C isotherm to be 7.4 km. However, thermal blanketing by low conductivity sedimentary rocks in several sedimentary basins, heat advection in regional groundwater systems, and the spatial distribution of radiogenic heat in the granitic upper crust create a complex thermal pattern for the midcontinent. We identify several sedimentary basins, one general area and one specific site as having good potential for EGS development.

Sedimentary Basins. The thermal blanketing effect of thick low thermal conductivity sediments in several basins, i.e., Williston, Kennedy, Denver, and Powder River, causes high geothermal gradients in regions with average heat flow. Heat flow in these basins ranges from 45 mW m^{-2} to 75 mW m^{-2} and the projected depth to the 150 °C isotherm lies between 4.5 km and 2.7 km respectively. Temperature projections in the sedimentary basins are based on measured thermal conductivities from core samples from the Williston Basin. We believe this approach is valid because all of the basins contain equivalent lithostratigraphy. Measured temperature vs. depth profiles in each of the basins show high temperature gradients (Γ>50 K km^{-1}) in the low thermal conductivity (1.2 W m^{-1} K^{-1}) Mesozoic and Cenozoic clastic rocks and lower temperature gradients (Γ<21 K km^{-1}) in the high thermal conductivity (2.7 W m^{-1} K^{-1}) Paleozoic carbonates. We suggest that the deeper portions of the Denver, Williston, and Powder River basins are good targets for EGS development due to favorable temperatures and permeable rocks containing producible water. Geothermal water could be produced from the permeable sediments and allowed to drain back into the source formation through existing but abandoned exploration and production wells. This concept has advantages over the "hot-dry rock" scheme in significantly lower drilling and completion costs and in not requiring an external water supply.

Advective Systems. Gravity-driven regional groundwater flow causes anomalous heat flow over an area of about 80,000 km^2 in south central South Dakota and north central Nebraska. Data from 21 conventional heat flow heat flow holes and 43 bottom hole temperatures show a systematic variation in heat flow from 20 mW m^{-2} in the recharge zone on the eastern edge of the Black Hills to 140 mW m^{-2} in the discharge zone in central South Dakota. Flow is in a 600 m thick confined Paleozoic aquifer system that crops out on the margins of the Black Hills, reaches depths of 2 km in the Kennedy Basin, and forms a subcrop contact with the Dakota Group in the region of high heat flow. A temperature vs. depth profile measured in a gas exploration well that was cased and completed as a heat flow site near Burton, NE, exhibits an abrupt change in gradient from 96 K km^{-1} to 73 K km^{-1} in the Paleozoic aquifer. Depth to the 150 °C isotherm in the anomalous region is approximately 4 km. A similar flow system occurs along the Chadron Arch in western Nebraska (112 mW m^{-2}) also is due to gravity-driven regional groundwater flow. EGS development in both of these regions would be in the crystalline basement

High Radioactive Heat Production. A site in southeastern Nebraska has an anomalously high heat flow of 106 mWm^{-2}. The data are from a mining exploration borehole in a carbonatite body with high radioactive heat production. Geophysical data suggest that the carbonatite body is approximately 7 km in diameter. Based on a temperature gradient of 60 K km^{-1}, we project that the 150 ^{o}C isotherm would be reached at a depth of approximately 2.5 km.