GEOTHERMAL INVESTIGATIONS IN NEBRASKA

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Introduction

The geothermal regime of Nebraska was not known by any direct evidence prior to the commencement of a U.S. Department of Energy sponsored study in 1979. Although some interpretations of this geologic province indicated a typical midcontinent heat flow (Roy et al., 1972; Combs and Simmons, 1973; Lachenbruch and Sass, 1977), other studies suggested that anomalously high subsurface temperatures might exist in parts of the state (Swanberg and Morgan, 1979; Schoon and McGregor, 1974). The significance of these data and their relevance in the design of the geothermal resource assessment of Nebraska were discussed by Gosnold (1980). The resource assessment strategy included acquisition of heat flow data, temperature-gradient measurements in all available wells, an evaluation of the bottom-hole temperature data for more than 14,000 oil and gas wells, and preparation of a 5-mgal contour interval residual Bouguer gravity map. For reasons discussed elsewhere the bottom-hole temperature data from oil and gas wells are not particularly useful. However the other data excluding the gravity, map which is in preparation, have proved to be a successful approach to the resource assessment.

Heat Flow and Resource Assessment

Twenty-nine heat flow sites were selected throughout the state and included both the suspected anomalous and normal heat flow areas. Heat flow for most of Nebraska ranges from 40 mW/m^2 to 60 mW/m^2, but two laterally extensive areas (Fig. A-14) with heat flows as high as 120 mW/m^2 have been discovered (Gosnold et al., 1981). The high heat flow in the Nebraska panhandle appears to be due to slow, updip flow in deep aquifers in the Denver-Julesburg basin and corresponds to the eastern margin of the basin in Nebraska. Fig. A-15 illustrates how temperature gradients measured in eight

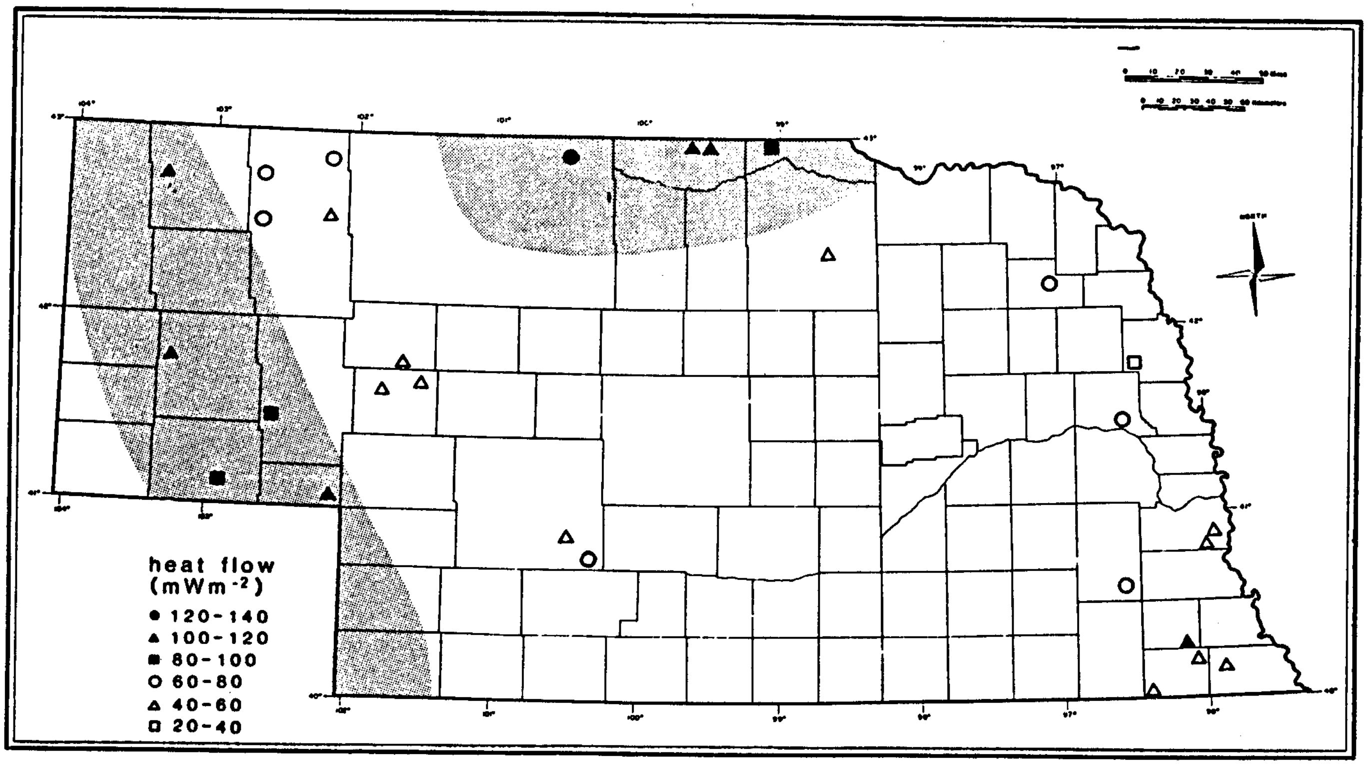

Fig. A-14.

Nebraska Heat Flow Data. High heat flow zones are shaded but the limits of the zones are inferred and are not certain. The high heat flow zone in western Nebraska may be due to updip flow toward the northeast from the Denver basin. The origin of the high heat flow zone in north-central Nebraska is discussed in the text.

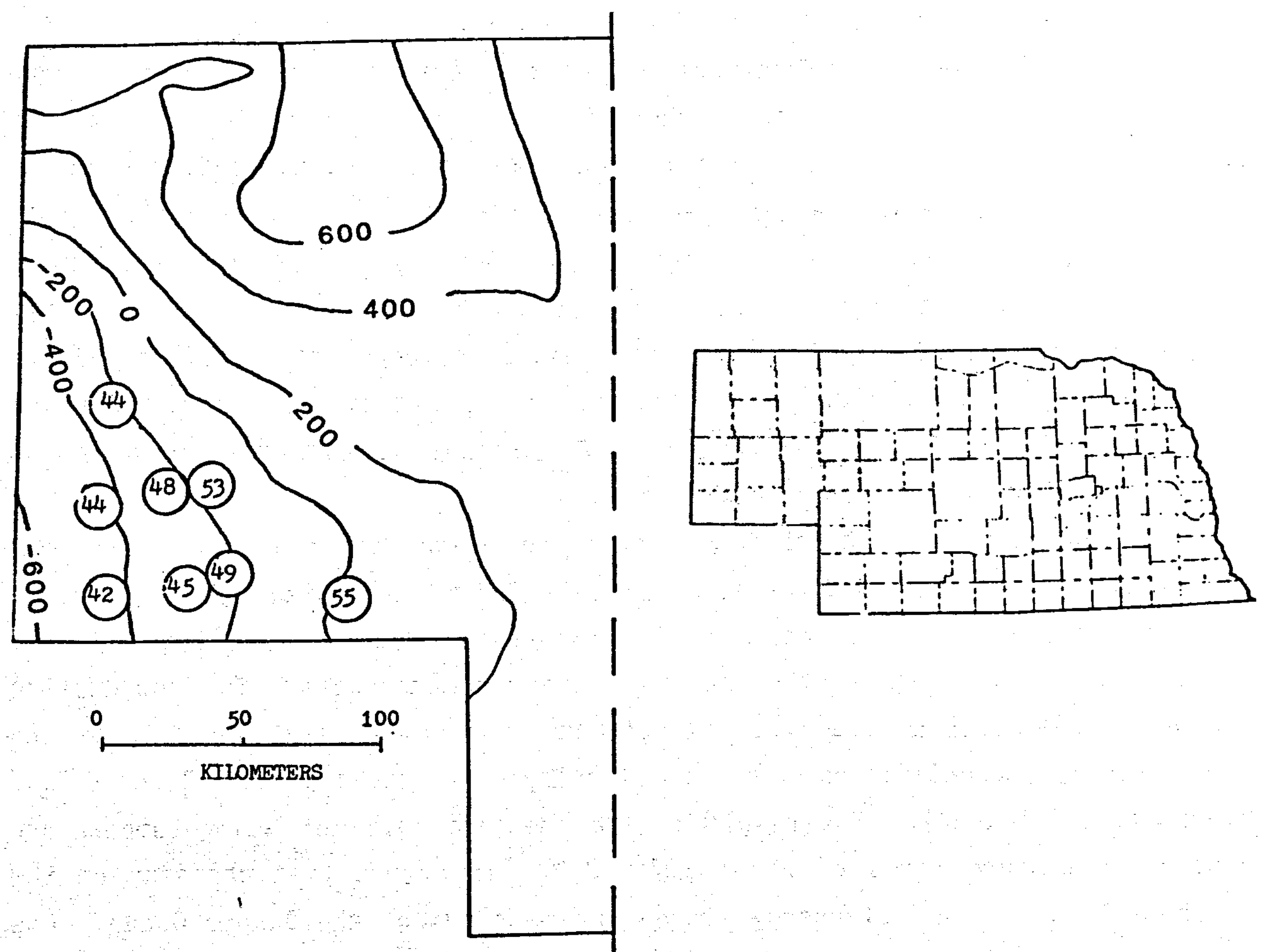

Fig. A-15.
Equilibrium temperature gradients for eight deep wells are given in the locating circles. Structure contours for the Dakota are given in meters with datum as mean sea level. The area of the enlarged map is shaded in the map above.

deep wells (1.2 to 1.8 km) relate to structure contours on top of the Dakota Group (Cretaceous). Modeling studies of the effects of updip water flow within the lower sand units of the Dakota Group suggest that a flow rate of about 0.4 to 0.6 m/yr could produce the subsurface temperatures observed above that horizon.

The high heat flow in north-central Nebraska is not easy to explain. Four heat flow sites in the area range from 100 mW/m^2 to 140 mW/m^2, and temperature gradients logged in 14 deep water wells range from 50 K/km to 90 K/km. Updip water flow is an unlikely explanation for the high heat flow because the sediments dip at very shallow angles. A more likely explanation is that upward flow along fractures enters aquifers such as the Dakota Group and flows laterally, causing the high heat flow. A third possibility is that the Precambrian basement rocks contain high amounts of uranium and thorium and have high heat generation values. We have no firm data as yet that could help in the interpretation of this region. However, by midsummer of 1982 we expect to obtain a temperature log in a recently completed heat flow hole that bottoms in Precambrian granite. The hole has been logged to a depth of 530 m, which reaches upper Paleozoic Carbonates, and the temperature log gives no indication of hydrologic disturbances. At present we can only speculate on the source of heat in this region.

We have obtained equilibrium temperature measurements in more than 100 additional wells; and, we have combined this information with heat flow data, thermal conductivity data, and stratigraphic data from electric logs of deep wells. These data were synthesized with the assumption that, in a conductive thermal regime, subsurface temperatures are determined by the heat flow and the thermal conductivities of the lithologic units present (Gosnold and Eversoll, 1981; 1982). The result is the identification of a low-temperature geothermal resource area of about 107,000 km^2 in extent that contains on the order of 1000 x 10^{18} J of energy stored in the sands of the Dakota Group. One of the primary reasons for the existence of this low-temperature geothermal resource is that most of the stratigraphic section overlying the Dakota Group in Nebraska consists of shales that have thermal conductivities of around 1.1 W/m/K. Consequently the geothermal gradients within these thick (up to 2 km) shale sections are approximately 50 K/km even where the heat flow is not anomalously high (Fig. A-16).

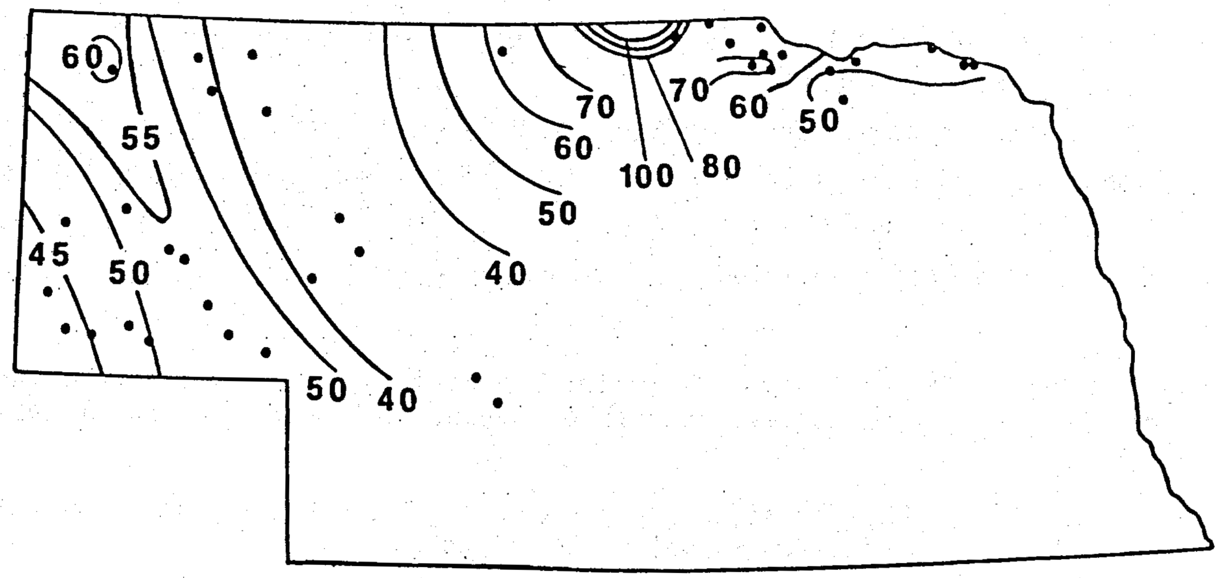

Fig. A-16.
Geothermal gradients from equilibrium temperature logs.

Hot Dry Rock Prospects

Extension of the present data to deeper regions in search of higher temperatures becomes mostly speculation. We have very little information on the amount of radioactive heat generation in the Precambrian basement rocks, but we are attempting to interpret what is available. Small samples of drill cuttings and some few core samples of basement rocks have been recovered during the drilling of deep, mineral-exploration holes. German (unpublished Masters Thesis) used fission track mapping techniques to investigate the nature of uranium occurrences in these samples. In general he has found that in several instances the amount of uranium contained in secondary minerals equals or exceeds the total uranium in primary minerals in these samples. It has been suggested (Gosnold, 1976; 1978; Gosnold and Swanberg, 1980) that uranium in secondary minerals in intrusive rocks represents enrichment in uranium that occurred during interaction between the rocks and convecting meteoric ground water. We are investigating the possibility that the fission track data may give some indication of heat generation in the basement rocks. If this method of study proves to be valid it could be useful in estimating upper crustal temperatures in regions with covered basement rocks. It should be pointed out that the basement samples we have are too small for gamma-ray spectrometric determination of heat generation and are not available for destructive chemical analyses.

Calculations of temperatures in the basement rocks based on basement heat generation values ranging from 5 to 15 HGU indicate that drilling depths on the order of 5 km are to reach the 200° isotherm. In western Nebraska up to 3 km of this drilling depth would be in sedimentary rocks.

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