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PRELIMINARY REPORT ON THE GEOTHERMAL RESOURCE POTENTIAL OF NEBRASKA

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ABSTRACT

Preliminary results of the geothermal resource assessment of Nebraska indicate that about 74% of the state overlies regions having temperatures of at least 40°C at a depth of one kilometer. In regions covering about 67% of the state the 40°C isotherm lies within the sedimentary section at depths of about one kilometer and intersects aquifers which are considered potential geothermal resources. A zone of anomalously high geothermal gradients in South Dakota appears to extend into northeastern Nebraska and is evidently due to warm water in the Dakota formation. The preliminary results of heat flow determinations within the state indicate that heat flow in western Nebraska may be as high as 2.0 HFU (83.6 mw/m^2).

INTRODUCTION

The goal of the DOE funded geothermal resource assessment program in Nebraska is to identify and evaluate geothermal resources on a statewide basis. The project is designed to fulfill three basic tasks, i.e., the compilation of existing data, the collection of new data which includes the drilling of about 30 shallow (150 meter) heat flow holes as well as measuring temperature gradients in available wells, and finally the preparation of maps summarizing the geothermal resource potential of the state. The project commenced in April, 1979 and has progressed through the initial stages of data collection to the point of interpretation of existing data and planning for acquisition of requisite new data.

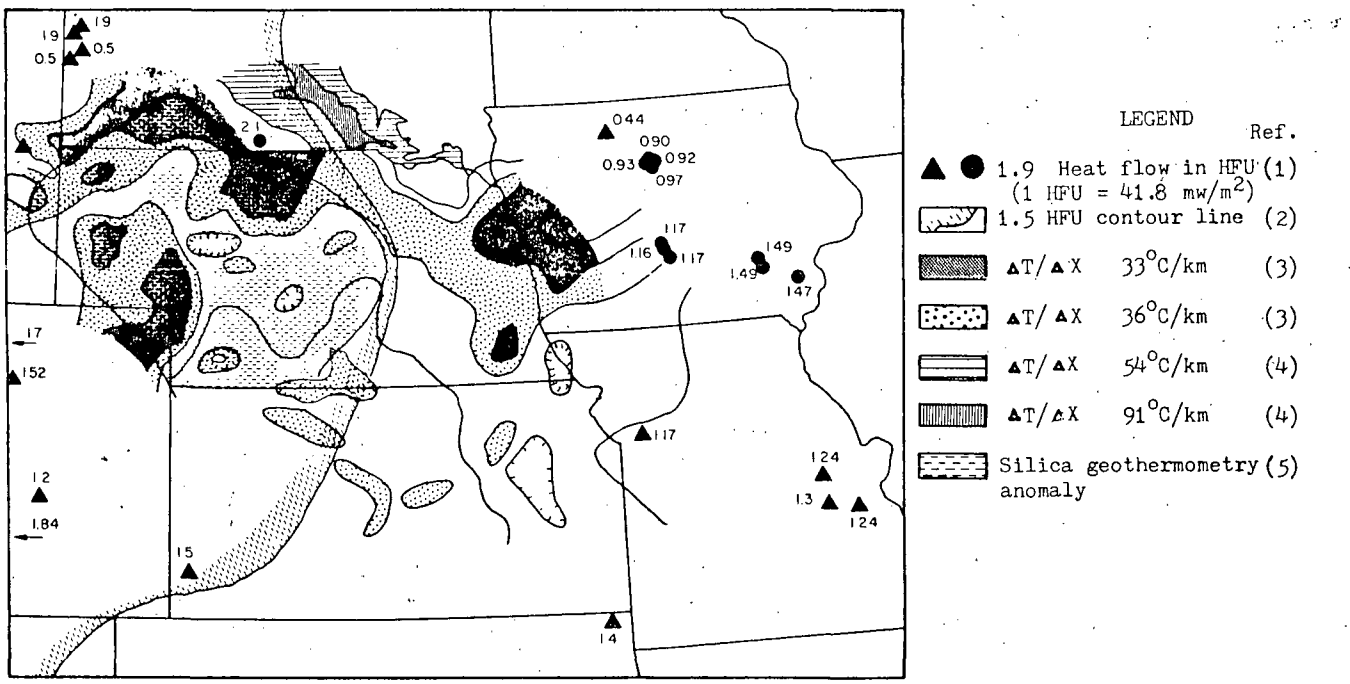

Figure 1. Summary of published data on the geothermal regime of Nebraska. (References: 1 - Combs and Simmons, 1973; 2 - Sass et al., 1976; 3 - AAPG Geothermal Gradient Map of North America, 1976; 4 - Schoon and Mcgregor, 1974; 5 - Swanberg and Morgan, 1979)

Existing Data.

The compilation of existing data on the geothermal regime of Nebraska is summarized in Figure 1. These data were assembled from a number of sources including regional heat flow studies (Roy et.al., 1972; Combs and Simmons, 1973; Sass et.al., 1976), a silica-geothermometry study (Swanberg and Morgan, 1979), the AAPG geothermal gradient map of North America (AAPG, 1976), and geological studies by the Nebraska and South Dakota geological surveys (Souders, 1976; Schoon and McGregor, 1974). Prior to 1979 there were no published temperature gradient or heat flow data for Nebraska other than the AAPG map, and most of the existing data are for the regions surrounding the state. Only the silica-geothermometry study and the AAPG map use data from within Nebraska.

Discussion of Existing Data.

The AAPG geothermal gradient map indicates that about 74% of Nebraska overlies regions with temperatures of 40°C at a depth of one kilometer and that the 50°C isotherm lies at depths ranging from 1.1 to 1.4 kilometers within these regions. However, not all parts of these regions have potential for geothermal resources. A necessary condition for low-temperature geothermal resources is the presence of an aquifer, but in some areas of eastern Nebraska the crystalline basement rocks lie above the 40°C isotherm. The regions in which the 40°C and 50°C isotherm lie within the sedimentary section are shown in Figure 2. In general, all parts of Nebraska west of a line from Valentine to Fairbury constitute a potential geothermal resource area. The regions indicated by darker shading in Figure 2 have temperatures of at least 50°C at depths of 1.1 to 1.4 kilometers. The bottom hole temperatures within the indicated areas were taken at depths exceeding one kilometer thus Figure 2 is considered a reliable representation of the potential resource area.

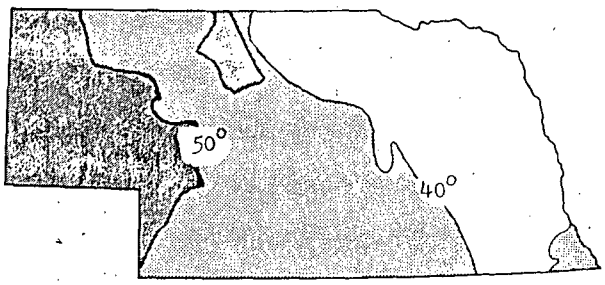

Figure 2. Regions where the 40°C and 50°C isotherms intersect the sedimentary section.

The geothermal gradient map of South Dakota (Schoon and McGregor, 1974) indicates a zone of anomalously high gradients that trends toward the southeast along the Missouri River valley and appears to continue into Nebraska. This zone coincides with the pattern of the AAPG geothermal gradient map and with the trend of a line of historical earthquakes in eastern Nebraska (Docekal, 1970). The strike of the earthquake zone coincides with a line connecting the offset segments of the mid-continent gravity high in Nebraska and Kansas. Maroney et.al., (1979) suggested that the earthquakes occur along a former transform fault that is still a zone of weakness in the crust. It is unknown if the coincidence of the high gradient zone and the line of earthquakes is significant.

Temperatures measured in twelve deep water-wells near the Nebraska-South Dakota state line in Boyd County, Nebraska (Souders, 1976) indicate that the Dakota formation, which underlies the area at a depth of about 300 meters, contains water at a temperature of about 29°C. A temperature gradient of 66°C/km measured in a 160 meter well in Boyd County in January, 1980 also indicates a temperature of about 29°C if it is extrapolated to 300 meters. From these data it appears that the high temperature gradient zone observed in South Dakota does extend into Nebraska and that warm water in the Dakota formation is responsible for the high gradients.

Existing data yet to be analyzed are the bottom hole temperatures of 13,000 oil and gas wells throughout the state. These data are being compiled along with detailed stratigraphic information for each well. It is expected that the compilation of these data will give a comprehensive view of the geothermal resource potential of the state.

Acquisition of New Data.

The compilation of existing data has been especially useful in planning the drilling sites for heat flow holes and for identifying areas of concentrated study. Figure 3 includes the locations of wells that have been logged to date and the locations of drilling sites selected for the 1980 field season. The geothermal gradient highs indicated by the AAPG map are all targets for drilling. The extent of the warm water in the Dakota formation will also be investigated by several drill holes and by logging of all available free wells in the northcentral and northeastern parts of the state. We have obtained access to three deep exploration wells with depths of 560, 648, and 680 meters in western Nebraska. They have been plugged at the bottom and filled with water for temperature gradient measurements. Samples of drill cuttings from those wells were collected during drilling by personnel from the state geological survey and heat flow values will be computed when the thermal conductivities are determined.

To date 12 heat flow holes have been completed but thermal conductivities have not been determined on all rocks. In general, heat flow is higher in the western part of the state and the data are in accord with the heat flow contour map of Sass et al., (1976). One anomalous heat flow value was determined in a deep mining test hole in a carbonatite in southeastern Nebraska. The high heat flow value of 2.6 HFU (108.7 mw/m^2)

is due to the combined effects of high heat generation in the carbonatite and thermal refraction in the Nemaha ridge.

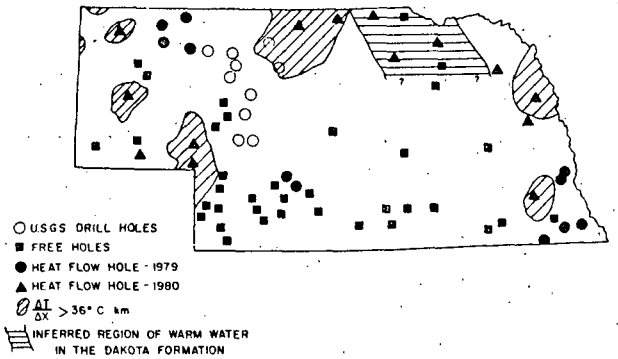

Figure 3. Summary of geothermal investigations in Nebraska.

One area of interest in the eastern part of the state is the red clastic material of Precambrian age that flanks the Kewanawan age gabbros associated with the mid-continent gravity high. (Figure 4). Little is known about the thickness of the red clastics but one well into the red clastic unit produced enough water to fill a large lake near Omaha. The geothermal gradients in the region of the red clastics are on the order of 33°C/km but it is not anticipated that the gradients are that high within the Precambrian sedimentary section. The Paleozoic sedimentary cover in the region is about 350 meters thick and it is estimated that the Precambrian sediments need to be at least 600 meters thick to intersect the 40°C isotherm.

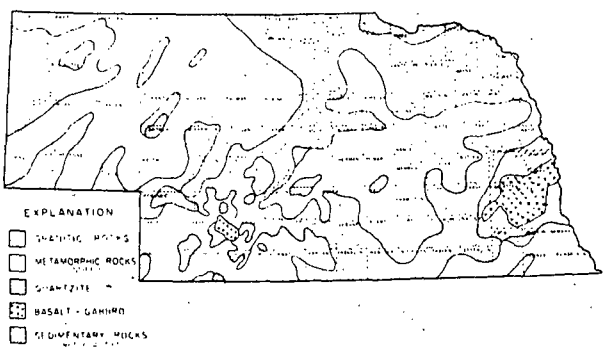

Figure 4. Precambrian Rock Types in Nebraska. (From Carlson, 1970, with permission.)

Future Studies.

The successful correlations between gravity lows and geothermal gradient highs (Costain, 1978; Hodge et.al., 1979) indicate that a Bouguer gravity map of Nebraska with a contour interval of one or two milligals would be a valuable tool for assessment of the geothermal resource potential of the state. We are investigating sources of existing gravity data on Nebraska and hope to add the compilation of that data and acquisition of new data to our program in the future.

The locations and nature of active faults in the eastern part of the state are vaguely known. A microearthquake survey along the suspected fault zone could identify and locate active faults which could contain geothermal systems. We are considering adding a microearthquake survey to our programs.

A state-wide chemical geothermometry study would also be a valuable aid to our assessment program. Application of the silica, Na-K, Na-K-Ca geothermometers to well waters around the state is being considered.

An aeromagnetic survey of the Nebraska panhandle is being considered to help in the interpretation of the high gradient values in that area. Also, Los Alamos Scientific Laboratory is planning to conduct an MT survey along a diagonal line from the southwestern corner of the Nebraska panhandle to Kimball, South Dakota. This additional information should add significantly to the interpretation of the thermal regime of western Nebraska.

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