LOW TEMPERATURE GEOTHERMAL RESOURCES IN NEBRASKA

REPORT OF INVESTIGATIONS: 1979-1980

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INTRODUCTION

The goal of the State Coupled Resource Assessment Program in Nebraska is to identify and evaluate low-temperature geothermal resources in the state. To achieve this goal we have undertaken the following three tasks: compile existing data on the geothermal regime of Nebraska, drill about 30 shallow (150 m) heat flow holes, and prepare appropriate maps to display the results of the first two tasks.

Existing Data.

One phase of the first task is the compilation of bottom-hole temperatures and other data from about 13,000 existing oil and gas wells in the state. This project is underway at the Conservation and Survey Division of the Nebraska Geological Survey where the data are filed on drilling reports. The data will be stored on magnetic tape and then processed to produce a geothermal gradient map of Nebraska. A correction for the mean annual surface temperature will be applied to the data. The map will be a considerable refinement of the information shown on the A.A.P.G. Geothermal Gradient Map of North America (A.A.P.G.,1976) which is based on only a few hundred data points within the state.

Another phase of the first task is the assimilation of data from other studies related to the geothermal regime of Nebraska. Data have been assembled from conventional heat flow studies, a silica geothermometry study, the A.A.P.G. map, and studies by the Nebraska and South Dakota Geological surveys.

Prior to 1978 no heat flow determinations had been made for Nebraska, but several studies gave data for the surrounding regions (Roy et. al., 1968;

Roy et. al., 1971; Sass et. al., 1971; and Combs and Simmons, 1973). Figure 1 shows the heat flow values for the regions surrounding Nebraska given by Combs and Simmons (1973). Combs and Simmons (1973) distinguish the Interior Lowlands Province with a heat flow of 1.4 H.F.U.(56 mw/m^2) from the Northern Great Plains Province with a heat flow of 2.0 H.F.U. (84 mw/m^2) and include Nebraska in the Southern Great Plains Province which has a regional heat flow about the same as that of the Interior Lowlands. Lachenbruch and Sass (1977) and Sass et. al. (1979) suggest that western Nebraska has a heat flow ranging from 1.5 H.F.U. to 2.5 H.F.U. (63 to 106 mw/m^2). Figure 2 is a reproduction of the heat flow map given by Lachenbruch and Sass (1977) and shows that the 1.5 H.F.U. contour line approximately parallels the boundary between the Great Plains and the Interior Lowlands and is additionally determined by one heat flow value in Kansas and one in South Dakota. Gosnold (1979) made ten heat flow determinations in Nebraska and generally confirmed the suggestions of Lachenbruch and Sass (1977). Gosnold (1979) identified a small heat flow anomaly in southeastern Nebraska that is caused by a combination of high heat generation in the basement rocks and by refraction of heat in the uplifted Nemaha Ridge (Figure 3).

Swanberg and Morgan (in press) show a significant heat flow anomaly that covers much of western Nebraska and includes parts of South Dakota, Wyoming, Colorado, and Kansas. The anomaly is inferred on the basis of geochemical analyses of well and spring waters and the application of the silica geothermometer (Fournier, 1973) and is outlined in Figure 4. Although recent heat flow determinations (Gosnold, 1979) confirm the existance of high heat flow in western Nebraska, too few data are available to confirm the inferred anomaly as a distinct heat flow province.

The Nebraska section of the A.A.P.G. map (A.A.P.G., 1976) indicates several regions with high geothermal gradients within the state (Figure 5). In general, the northern, western, and northeastern parts of the state have the highest gradients. The gradient values range from 40°C/km to 25°C/km.

The geothermal gradient map of South Dakota (Schoon and McGregor, 1974) shows an elongate zone of gradients greater than 91°C/km that is flanked by zones of gradients greater than 54°C/km in the southern part of the state. Figure 6 shows the high gradient zones have a linear trend which may extend into northeastern Nebraska. Seven water wells in Boyd County Nebraska penetrate the Dakota formation at depths ranging from 850'(259 m) to 1275'(387 m) and produce water at temperatures ranging from 60° F (15.5°C) to 82°F (27.7°C) (Souders, 1976). The water in these wells has an artesian head and is pumped from depths less than 75 m. One temperature gradient measured in a 300 m deep water well at Gross, Nebraska has a least-squares gradient of 66°C/km and may indicate temperatures of 30°C at the top of the Dakota formation. The source of the warm water in the Dakota formation is unknown, but it may be due to a subcrop connection with the Madison aquifer to the west.

Heat Flow Holes.

The majority of the drilling is planned for the 1980 field season so that the results from the data gathering tasks can be used to optimize site selections. Figure 7 shows the locations of holes that have been logged and the locations of drilling sites selected for the next field season. We intend to examine all possible high gradient areas and to carefully check the areal extent of the warm water in the Dakota formation.

We are continuing to search for any available free holes and have received permission to log about 30 deep water wells belonging to Burlington Northern R.R. in Nebraska. We have also aquired three gas exploration holes with depths of 560, 648, and 680 m in Arthur, County. These three holes were plugged and filled with water for gradient measurements. Samples of drill cuttings were collected by U.N. personnel during drilling and we will make heat flow calculations for these wells.

Discussion.

Figure 8 is a composite representation of existing data relevant to the geothermal regime of Nebraska. The zone of coincidence of the South Dakota thermal anomaly and the high gradient areas shown on the A.A.P.G. gradient map for eastern and northern Nebraska lies along the trend of historical earthquakes in that region (Docekal, 1970). The strike of the earthquake zone coincides with a line connecting the offset segments of the mid-continent gravity high (Woollard and Joesting, 1964). Maroney et al., (1979) suggested that the line of earthquakes follows the trend of a former transform fault which is still a zone of weakness in the crust. The fault zone is presently active for unknown reasons, and it's existance has promising implications for the geothermal resource potential of the area. Stream drainage patterns in the eastern part of the state between the line of earthquakes and the Missouri River are notably linear with a dominant strike of N 20^{o}W. The strike of the streams is parallel to the line of earthquakes and there is a possible connection between the drainage patterns and unknown faults in the basement. This eastern region will be carefully investigated for possible geothermal systems along fault zones.

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 assement 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 to our program in the future.

The locations and nature of active faults in the eastern parts 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 program.

A state-wide chemical geothermometry study would also be a valuable aid to our assessment program. Application of the silica, Na-K, and 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. Early in the coming spring, LASL will conduct an MT survey along a diagonal line from the southwestern corner of the panhandle to Kimball S.D. This additional information should add significantly to the interpretation of the thermal regime of western Nebraska.

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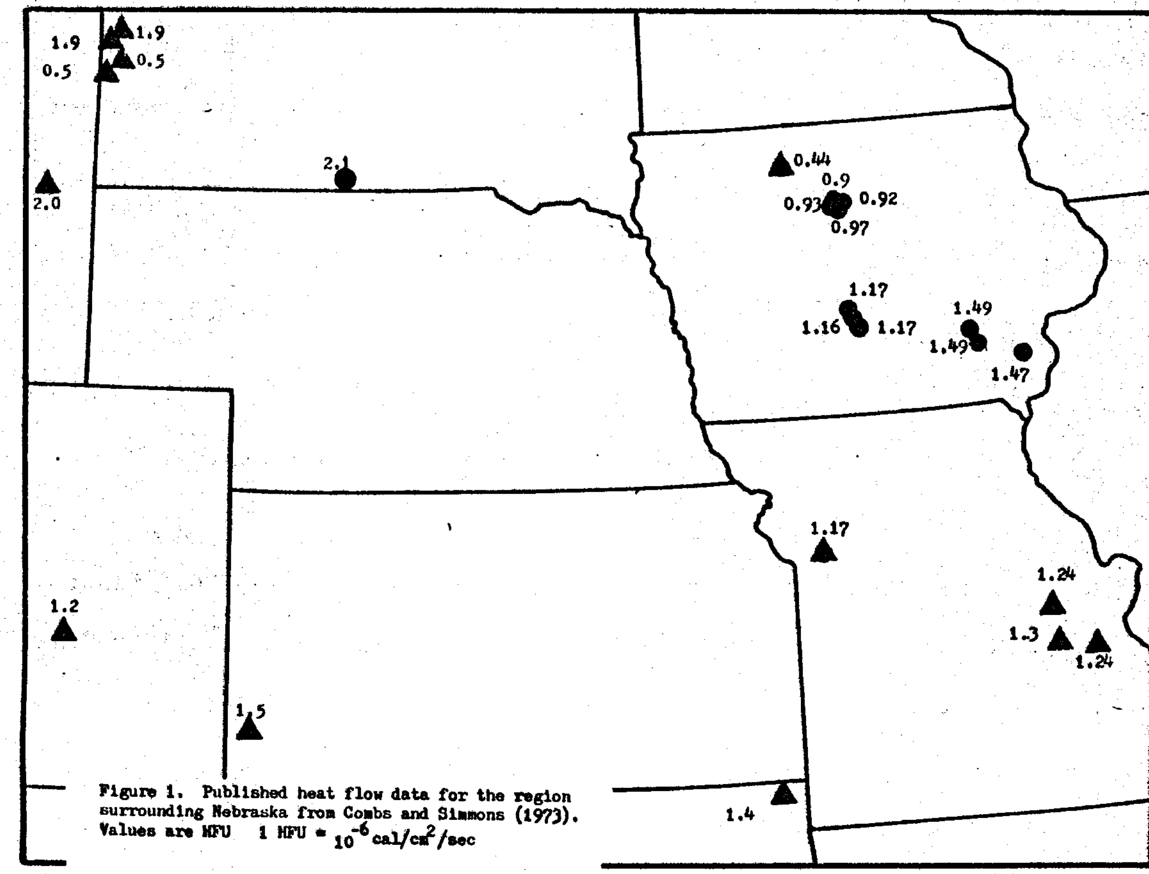


Figure 1. Published heat flow data for the region surrounding Nebraska from Combs and Simmons (1973). Values are HFU 1 HFU = 10^{-6} cal/cm^2/sec

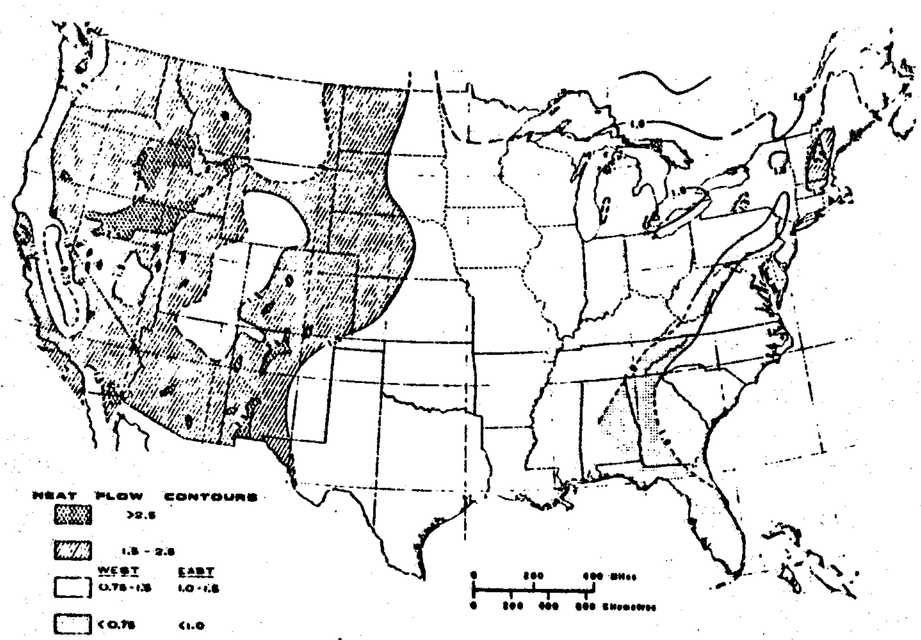


Figure 2. Reproduction of the U.S. heat flow map of Lachenbruch and Sass(1977).

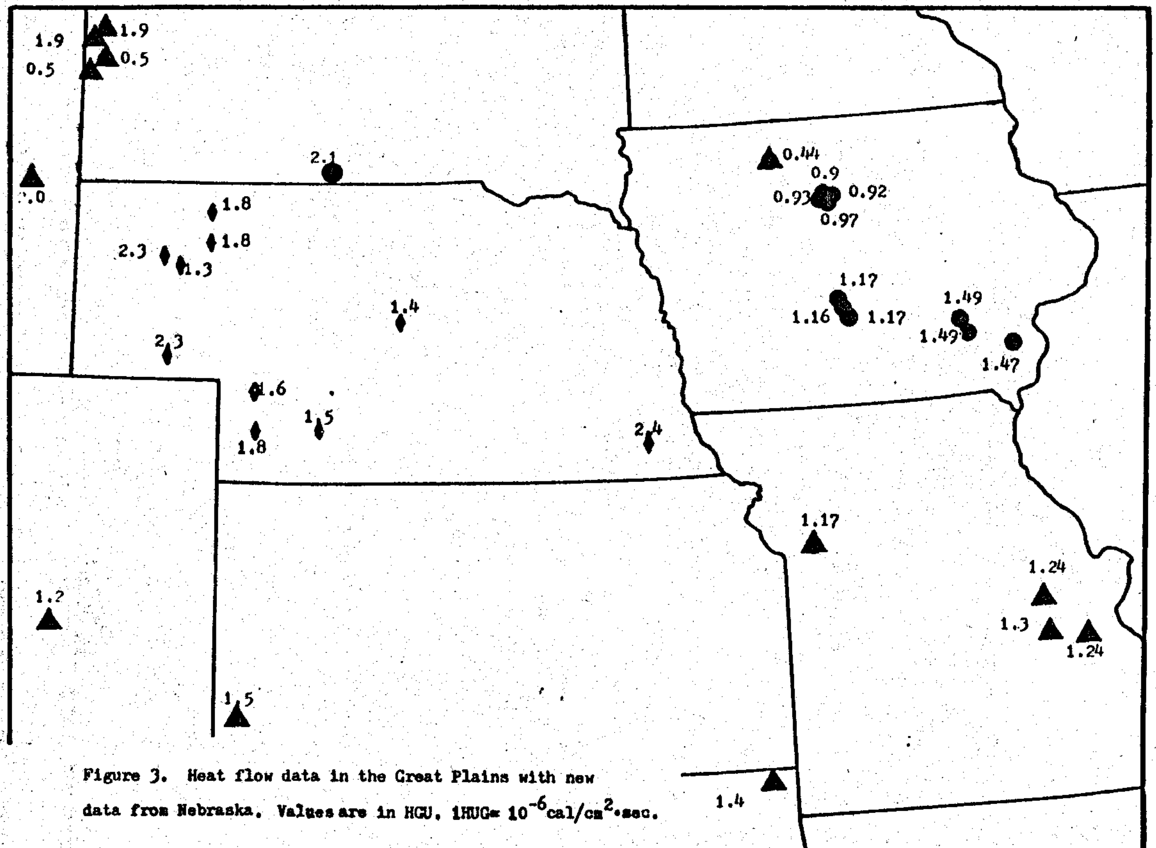


Figure 3. Heat flow data in the Great Plains with new data from Nebraska. Values are in HGU. 1HUG= 10^{-6}cal/cm^2·sec.

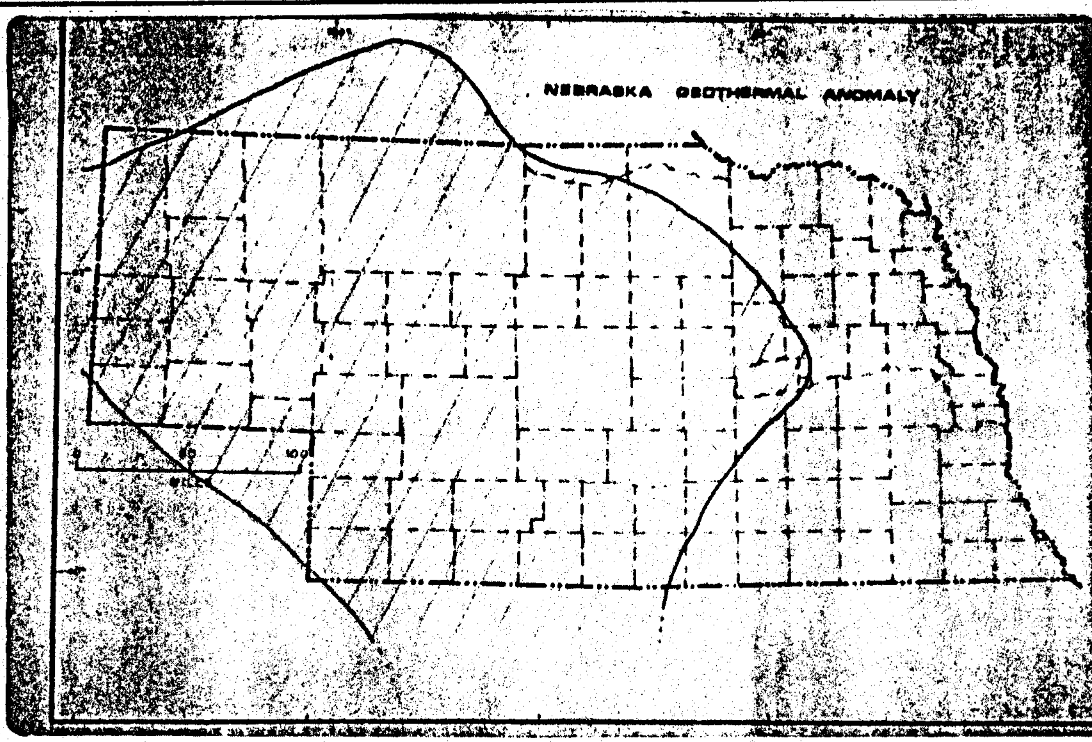


Figure 4. Cross-hatched area shows the extent of a heat flow anomaly inferred from the SiO_2 content of well waters by Swanberg and Morgan(1980).

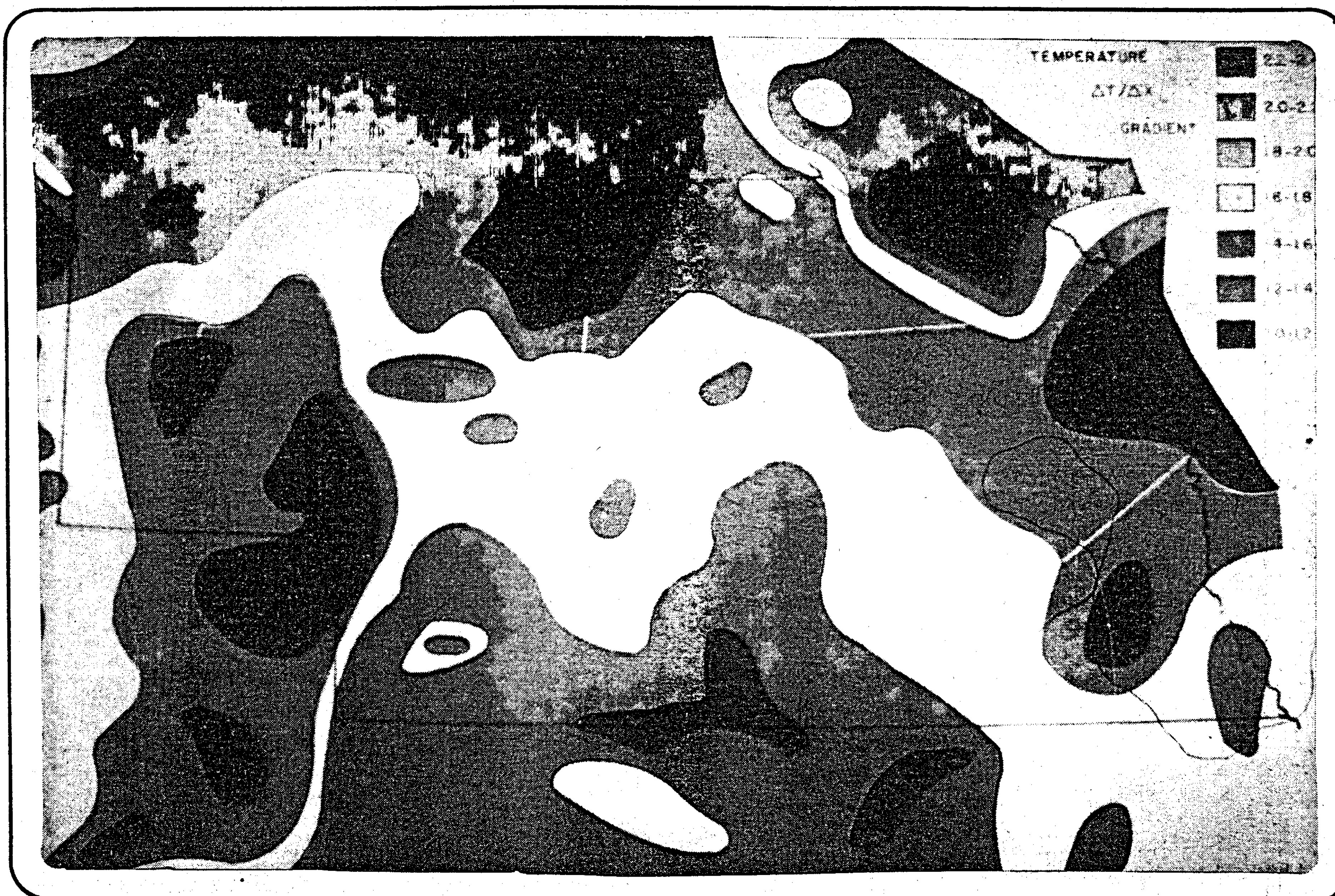
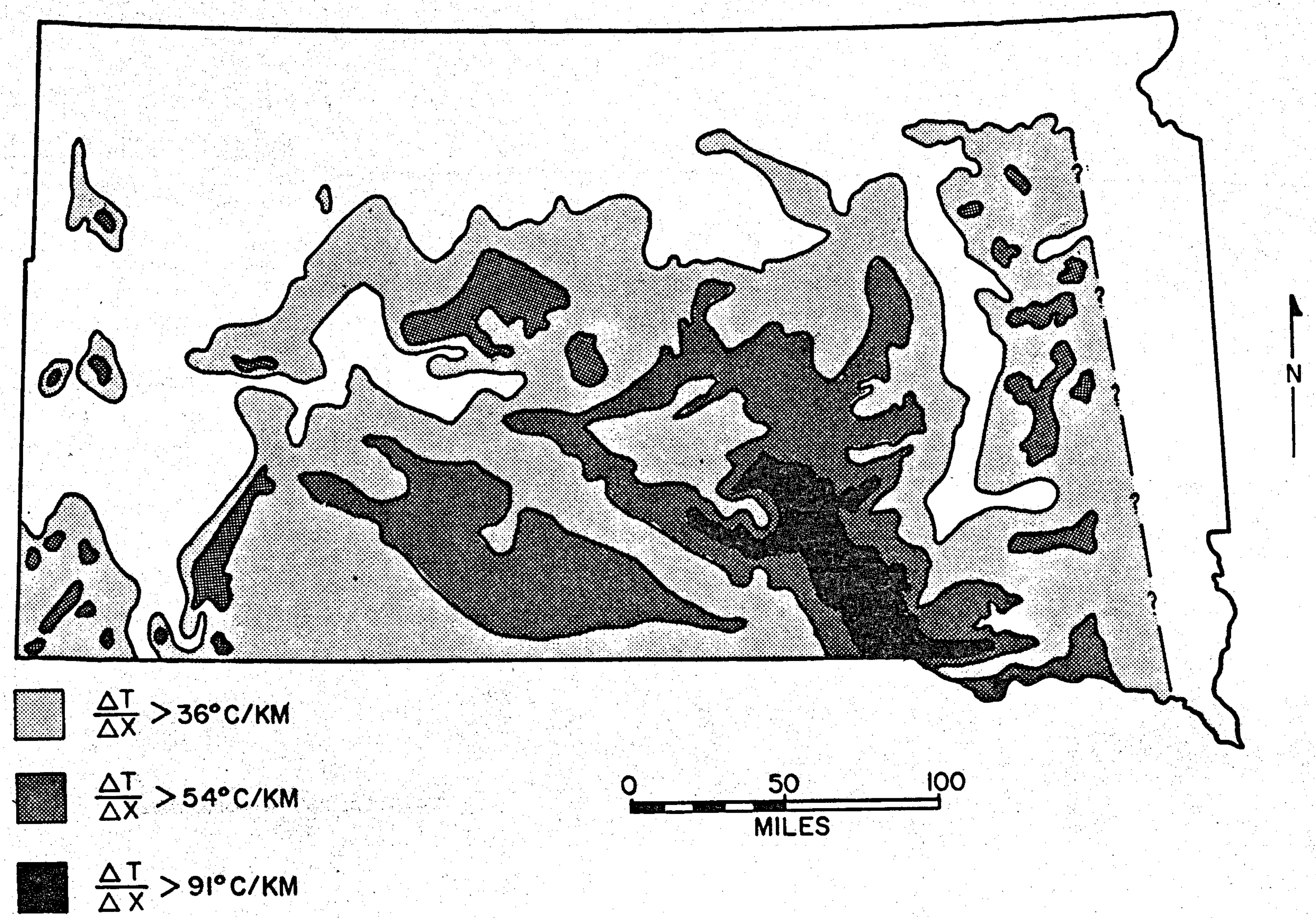


Figure 5. Nebraska section of the A.A.P.G. U.S.G.S geothermal gradient map.

GEOTHERMAL GRADIENT MAP OF SOUTH DAKOTA



from SCHOON and McGREGOR, 1974

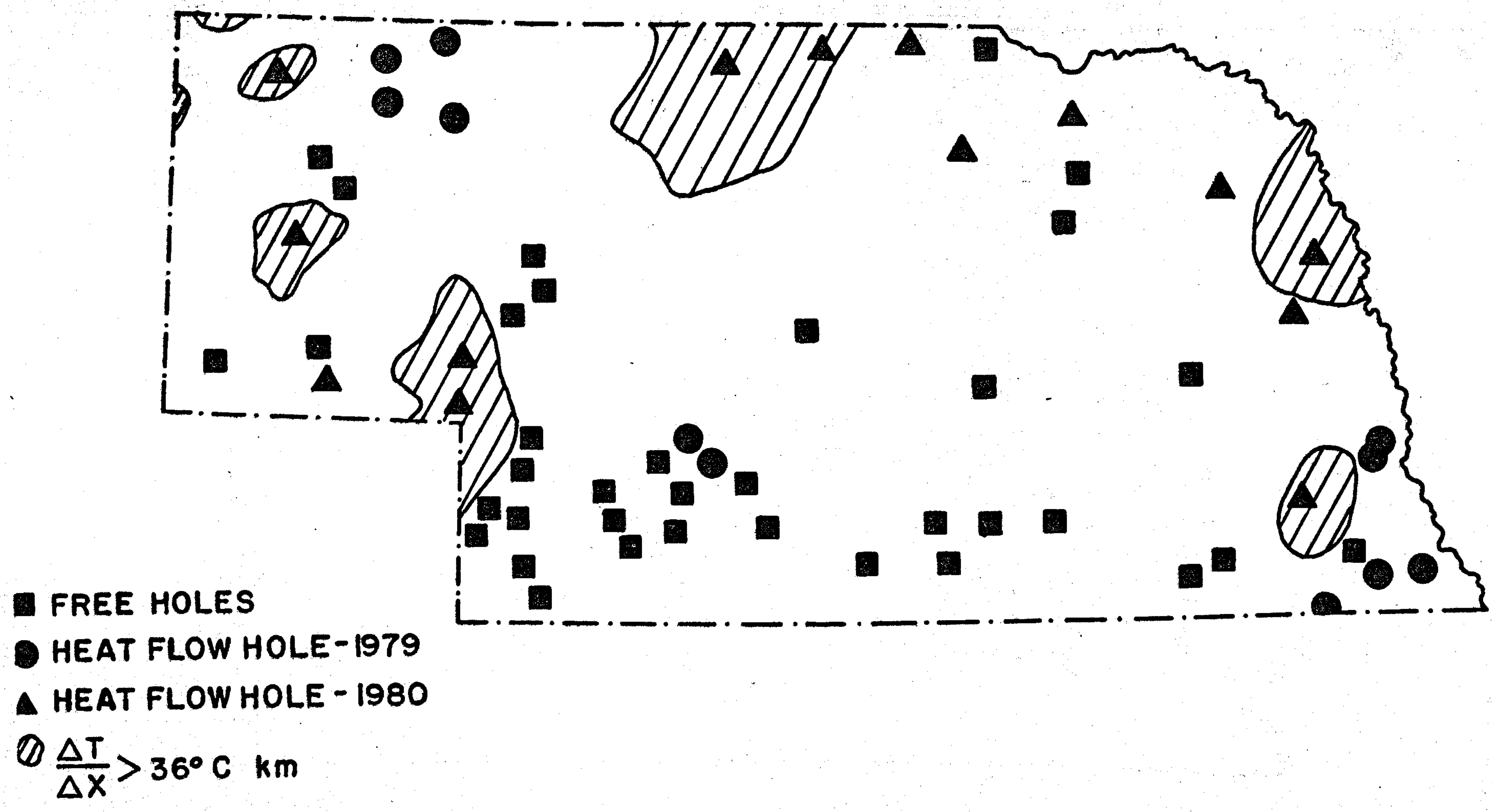
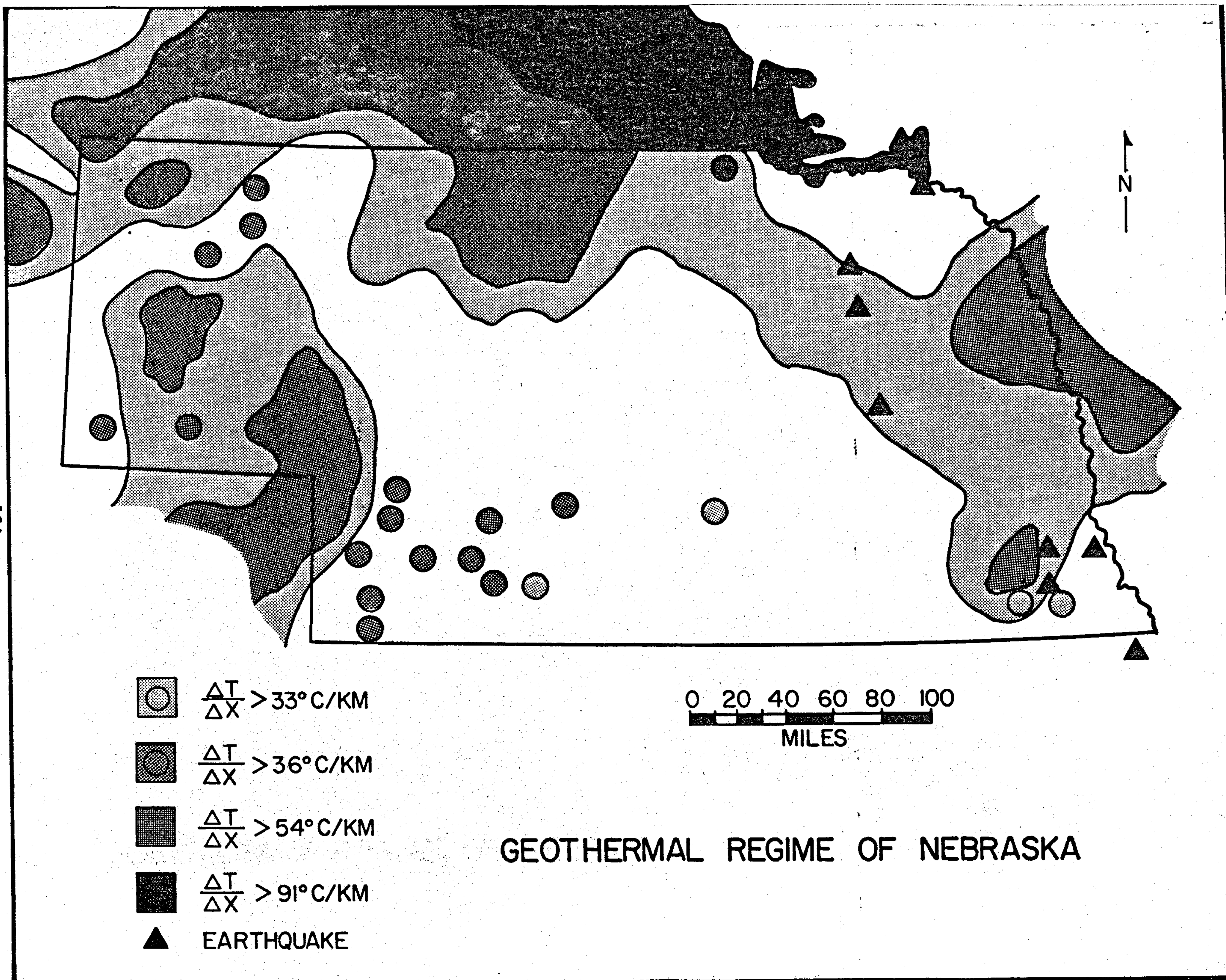


Figure 7. Locations of gradient and heat flow measurements.



GEOTHERMAL REGIME OF NEBRASKA