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AN EVALUATION OF THE HYDROTHERMAL RESOURCES OF NORTH DAKOTA

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The purpose of our study is to conduct a preliminary evaluation of the hydrothermal resources of North Dakota utilizing data contained in the oil and gas well files of the North Dakota Geological Survey and supplemented by additional data solicited from other cooperating state and federal sources.

Our stated goals can be summarized as follows:

1. To create a computer data management system capable of storing all the required data.
2. To produce computer generated maps that illustrate the variations in the bottom-hole temperature and depth data; the relationship between Williston Basin stratigraphy and the observed temperature and depth variations; and the water quality of potential hydrothermal reservoirs.

The data management system we are using is a location oriented computer library system named GEOSTOR. GEOSTOR was developed by Laramie Winczewski, a University of North Dakota geologist, with funds provided by the Surface Environment and Mining research group of the U.S. Forest Service. The data, from each oil and gas well drilled in North Dakota, contained in GEOSTOR consists of owner-operator, location, reference elevation, deepest formation penetrated, total depth, bottom-hole temperature, production information, available samples and cores, available geophysical data, and selected formation tops.

The North Dakota Geological Survey has purchased a Surface II computer contouring program which we are using to generate map presentations of the data stored in GEOSTOR.

Our data was collected and encoded during the period from March through October, 1979. The encoded data was incorporated into GEOSTOR and proofed during the period October through November, 1979. Preliminary mapping of the temperature and depth data and the stratigraphic data have continued since December, 1979.

In order to summarize our bottom-hole temperature and total depth data, we will generate apparent geothermal gradient and "slice" maps. The "slice" maps will display observed temperatures in various depth intervals, or minimum expected temperatures for depth intervals.

Our stratigraphic data will be summarized by producing systemic maps and structural and isopach maps of potential hydrothermal aquifers. The stratigraphic data will also help us evaluate potential hydrothermal aquifers by allowing us to map the geographical variations in the observed temperatures in the major aquifer systems.

The water quality data that we currently have in GEOSTOR consists of chemical analysis of water recovered during drill stem tests. This data contains the concentrations of major cations and anions, total dissolved solids, pH, and resistivity for the water collected in the tested intervals. This data will be summarized by generating maps of ion concentrations, total dissolved solids, and pH for each of the major aquifer systems.

The preliminary structural maps we have at this time are shown in figures 1-6. They include maps on the Precambrian, Cambrian Deadwood Formation, Ordovician Red River Formation, Silurian Interlake Formation, Devonian Duperow Formation and Mississippian-Madison Formation.

A preliminary apparent geothermal gradient map is shown in figure 7. This map is constructed from the bottom-hole temperature and total depth data contained in GEOSTOR and assumes a 40° mean annual air temperature (fig. 8). Areas of greater than average geothermal gradients ($>25^{o}C/km$) are present along the western border, along the northern border, and in the eastern one-third of the state. In the eastern one-third of the state, gradients of greater than $40^{o}C/km$ are not uncommon.

Although our results are preliminary at this time, it appears that the sands contained in the basal Cretaceous Inyan Kara group (Dakota Formation) may be a fairly shallow, widespread, potential hydrothermal aquifer. An interesting relationship exists between the subcrop of the Mississippian Madison Formation and the overlying Cretaceous Inyan Kara group in the eastern one-third of the state. A pre-Cretaceous paleogeologic map (fig. 9) shows the subcrop of the Mississippian Madison Formation (Charles, Mission Canyon, and Lodgepole intervals) in McIntosh, Emmons, and Logan counties. Total sandstone thickness in the lower Cretaceous (fig. 10) also reaches a maximum in these counties. It appears that hot Madison Formation water may be "leaking" into the basal Cretaceous sands resulting in the higher than average geothermal gradients shown in this area (fig. 7).

We are currently negotiating a Phase II proposal that would involve a program of heat flow determinations, detailed mapping of the potential hydrothermal aquifers indicated by Phase I, and further work on characterizing water quality in potential hydrothermal aquifers.

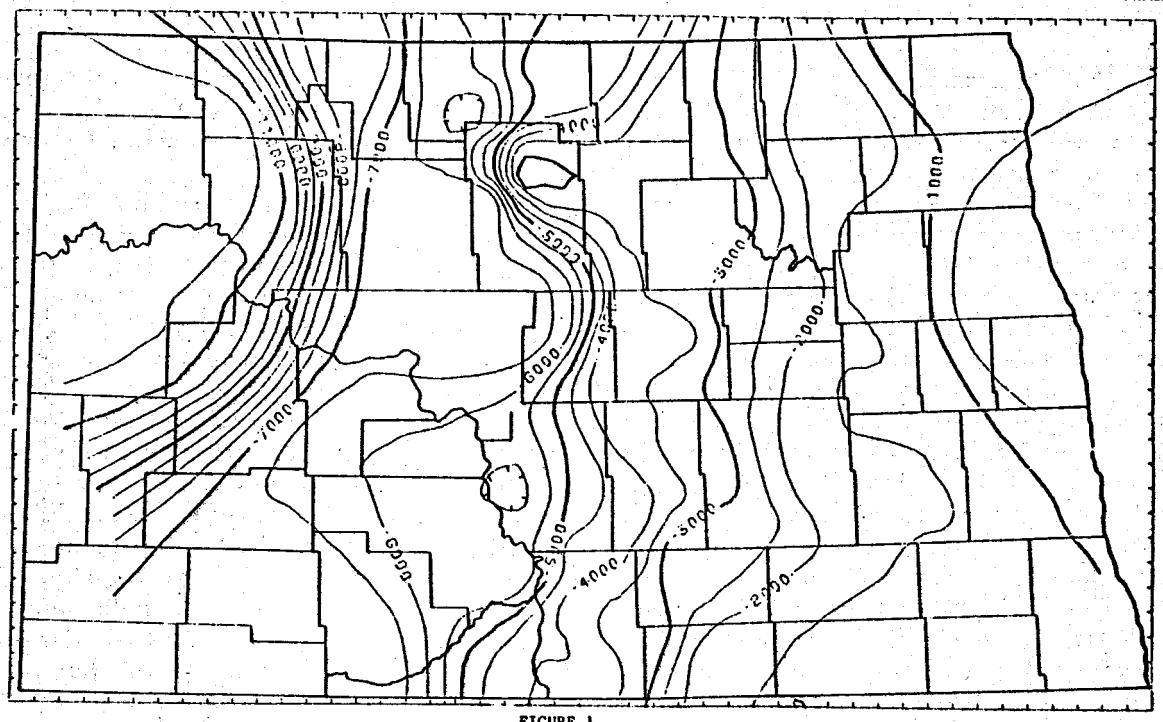

FIGURE 1

PRELIMINARY STRUCTURE MAP PRECAMBRIAN SYSTEM
CONTOUR INTERVAL-500 FEET
JANUARY 17, 1980

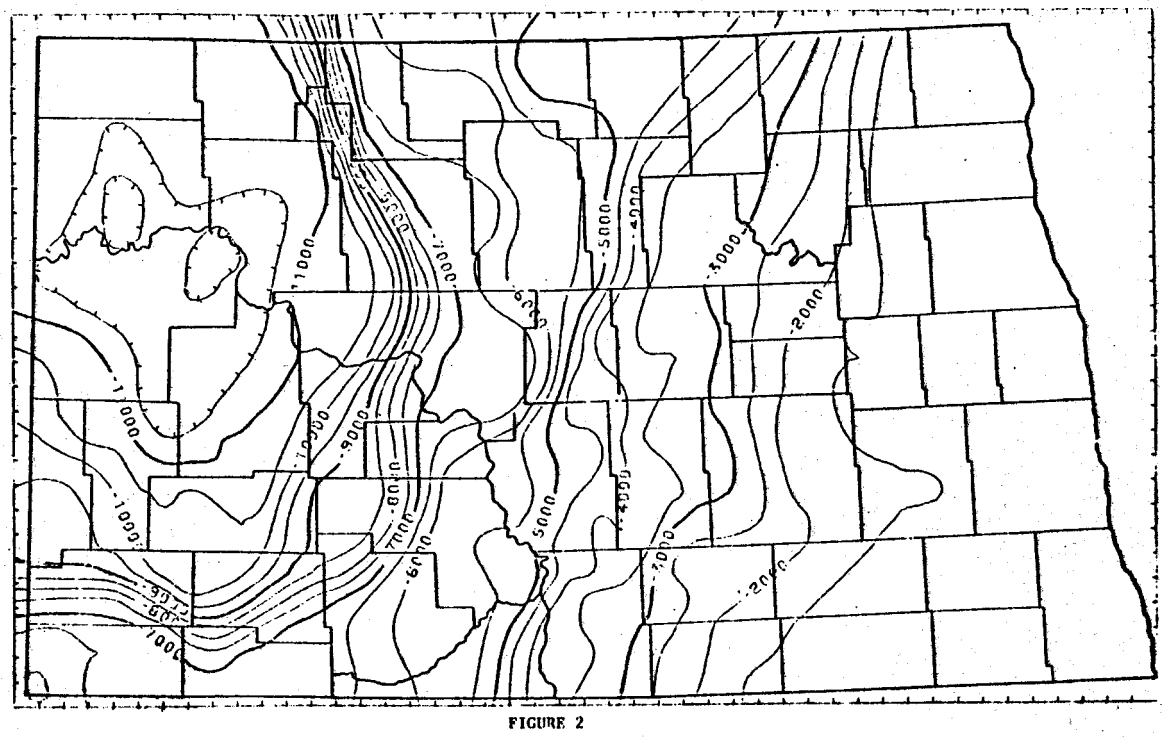

FIGURE 2

PRELIMINARY STRUCTURE MAP CAMBRIAN DEADWOOD FORMATION
CONTOUR INTERVAL-500 FEET
JANUARY 17, 1980

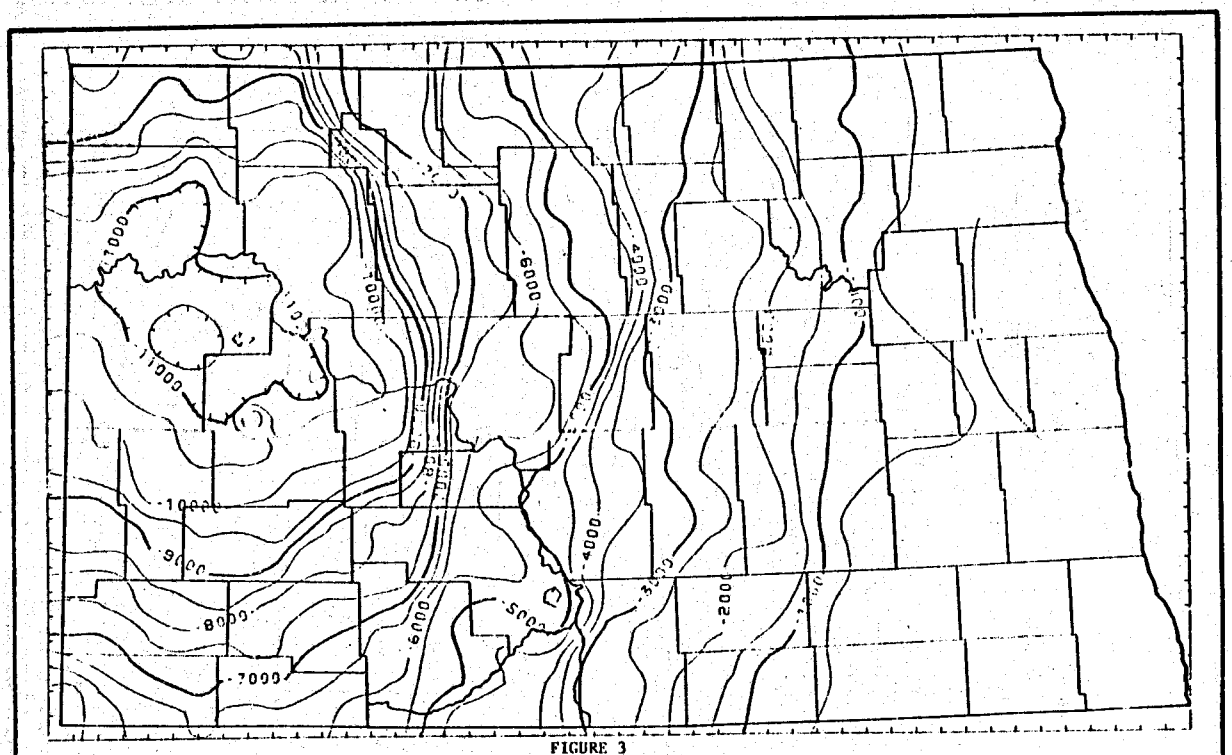

FIGURE 3

PRELIMINARY STRUCTURE MAP ORDOVICIAN RED RIVER FORMATION
CONTOUR INTERVAL-500 FEET
JANUARY 17, 1980

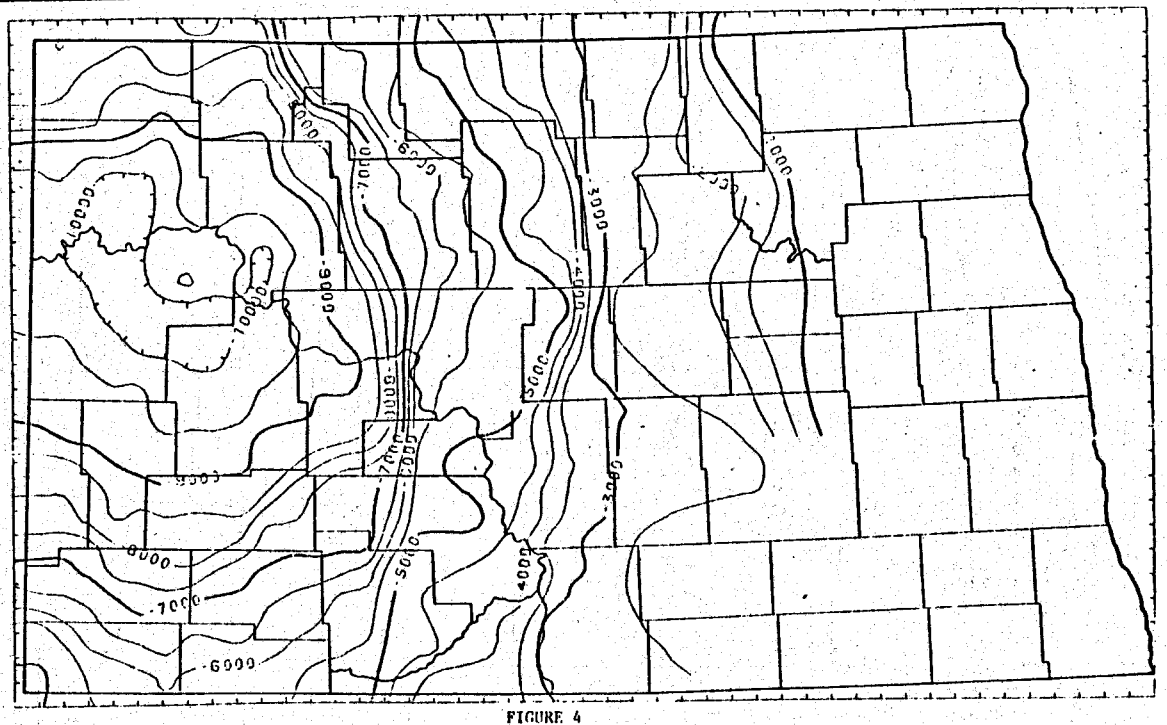

FIGURE 4

PRELIMINARY STRUCTURE MAP SILURIAN INTERLAKE FORMATION
CONTOUR INTERVAL-500 FEET
JANUARY 17, 1980

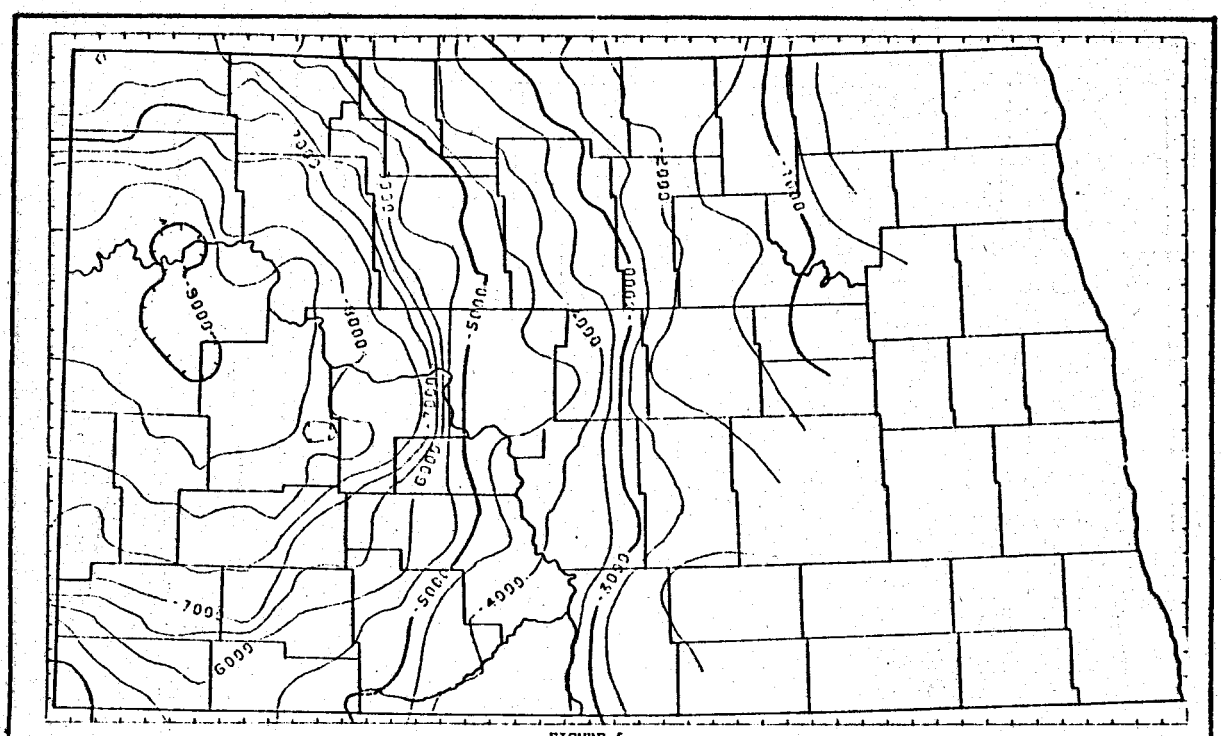

FIGURE 5

PRELIMINARY STRUCTURE MAP DEVONIAN DUPEROW FORMATION
CONTOUR INTERVAL-500
JANUARY 17, 1980

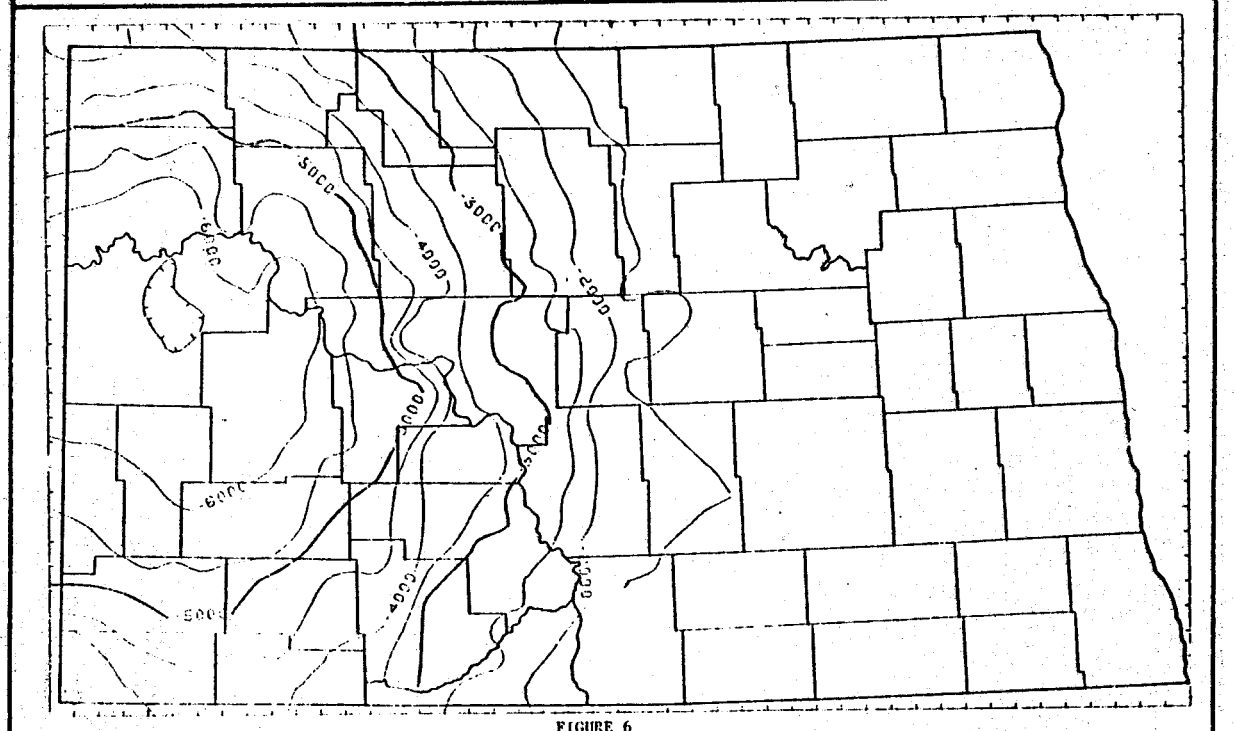

FIGURE 6

PRELIMINARY STRUCTURE MAP MISSISSIPPIAN MADISON FORMATION
CONTOUR INTERVAL-500
JANUARY 17, 1980

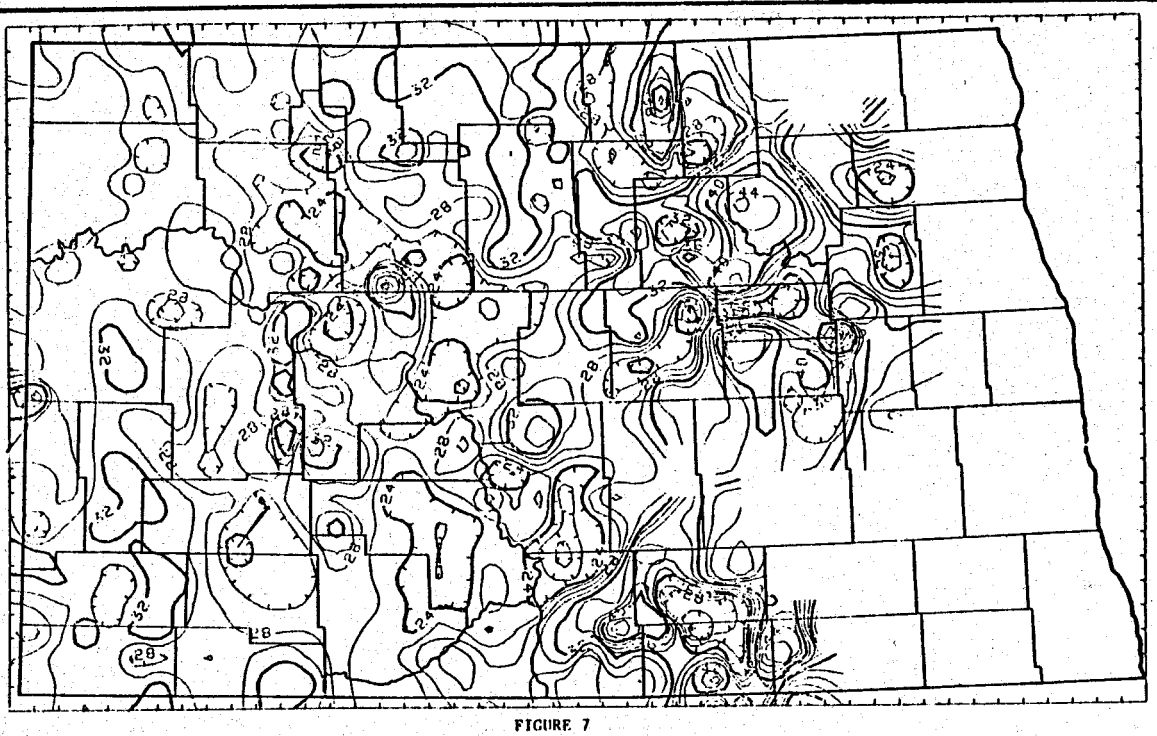

FIGURE 7

PRELIMINARY GEOTHERMAL GRADIENT MAP
CONTOUR INTERVAL-2°C/km
JANUARY 17, 1980

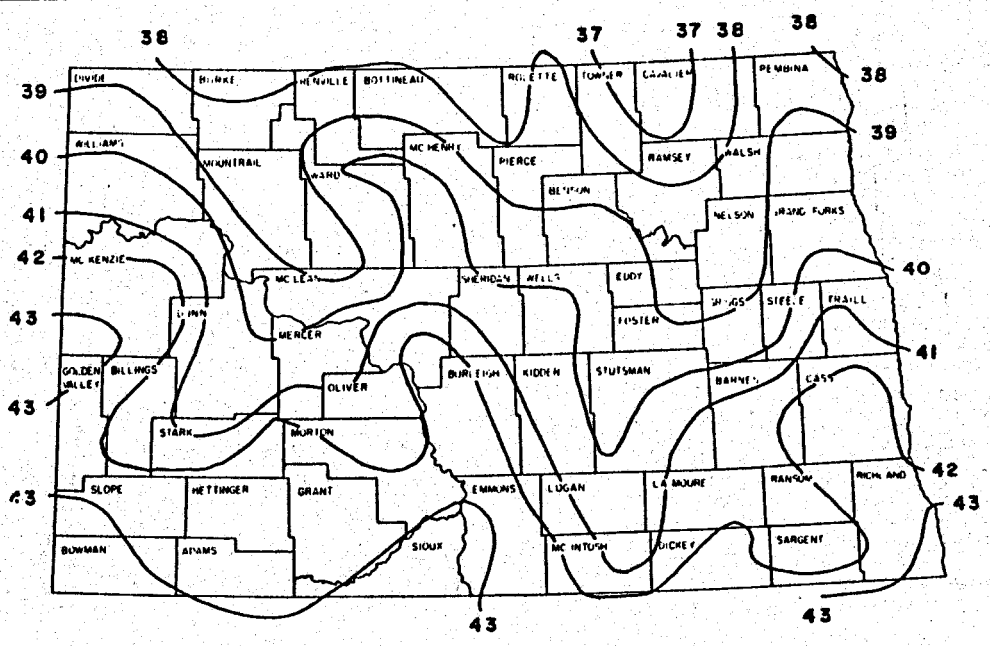

FIGURE 8

ANNUAL MEAN TEMPERATURE
FROM: JENSEN, 1972, CLIMATE OF N.DAK: NWS, NDSU, FARGO, ND

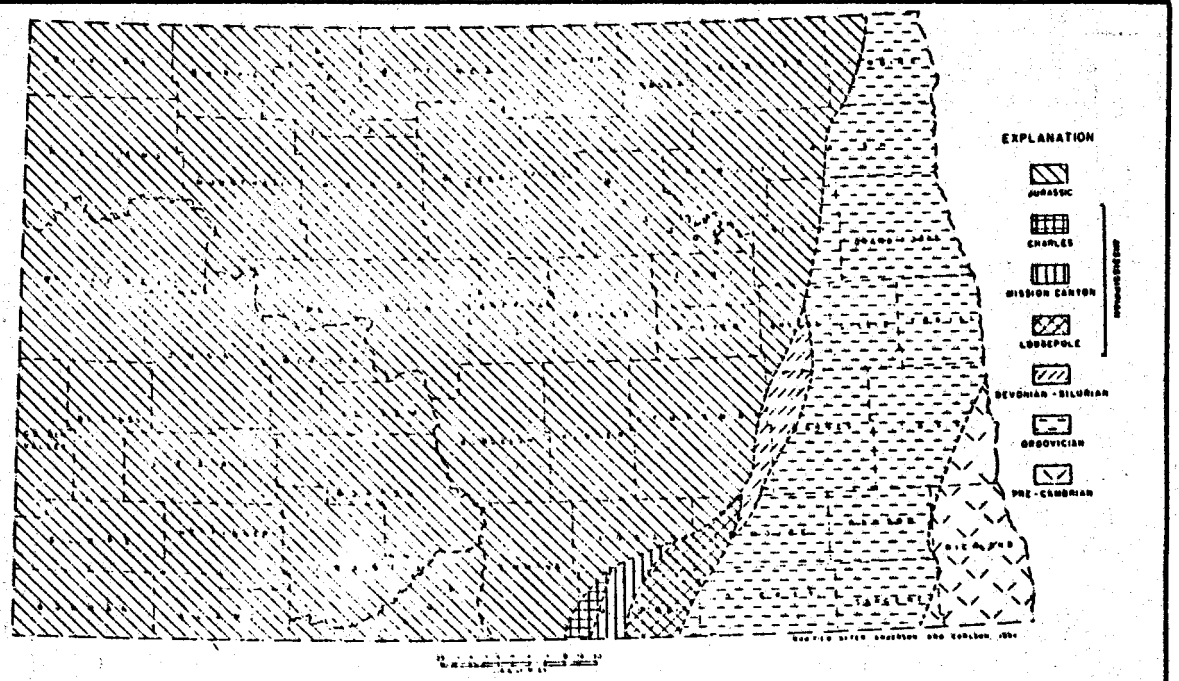

FIGURE 9

PRE-CRETACEOUS PALEOGEOLOGICAL MAP
FROM: DAN E. HANSEN, 1955, BULLETIN 29, NDGS

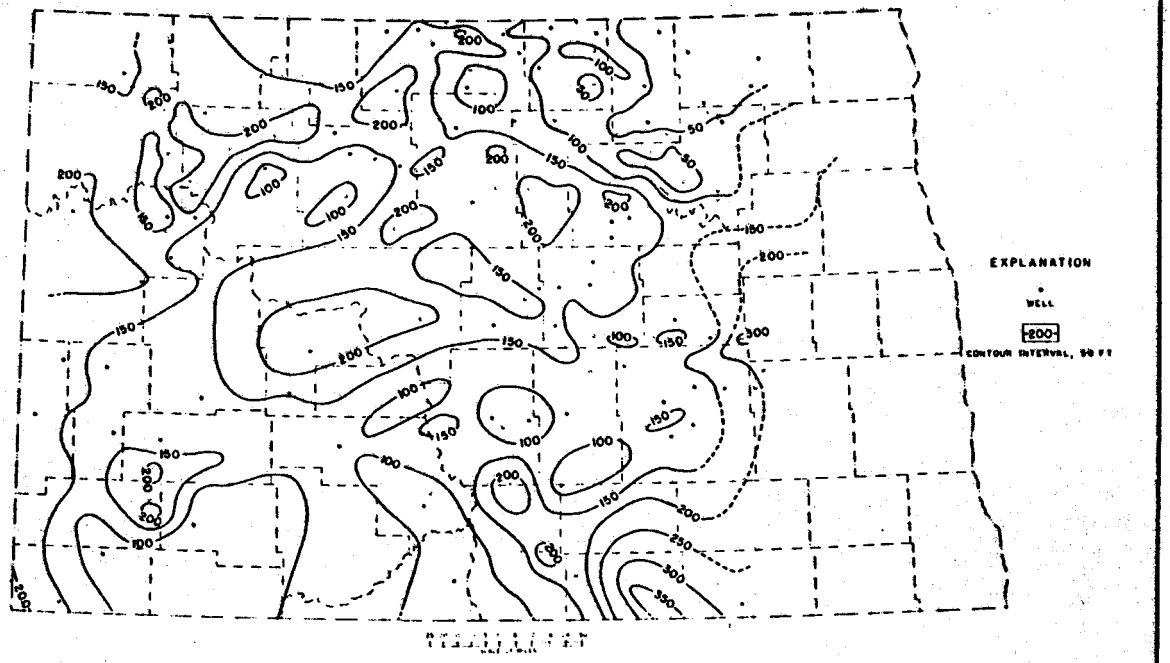

FIGURE 10

TOTAL SANDSTONE THICKNESS MAP OF THE GREENHORN TO JURASSIC INTERVAL
FROM: DAN E. HANSEN, 1955, BULLETIN 29, NDGS