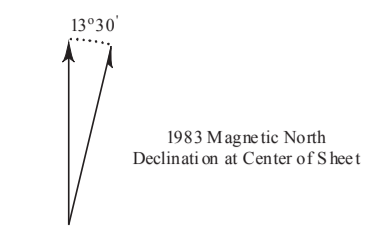


Deep Geothermal Resources: Estimated Temperatures on Top of the Inyan Kara Formation

Williston 100K Sheet, North Dakota

Plentywood	Crosby	Kenmare
Culbertson		Stanley
Sidney	Waford City	Parshall



Lorraine A. Manz

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Geothermal energy is a renewable resource capable of producing an uninterrupted supply of electrical power and heat. In stable sedimentary basins, low-temperature energy (< 100° F) is extracted from the shallow subsurface (-8-400 feet) for use in domestic and commercial heating and cooling systems. Historically, deeper, hotter resources in these regions have not been developed because they were not economical. However, as the nation explores ways to reduce its dependency on foreign energy sources and also begins to look more closely at renewable energy, accessing deep geothermal energy resources, particularly via existing oil and gas wells, is attracting a great deal of interest (<http://www.smu.edu/geothermal/>).

The Dakota Group contains the shallowest of four major geothermal aquifers that occur in the Williston Basin. The map shows calculated temperatures (°F) for the top of the Inyan Kara Formation, the oldest of the four rock units that comprise the Dakota Group (Fig. 1).

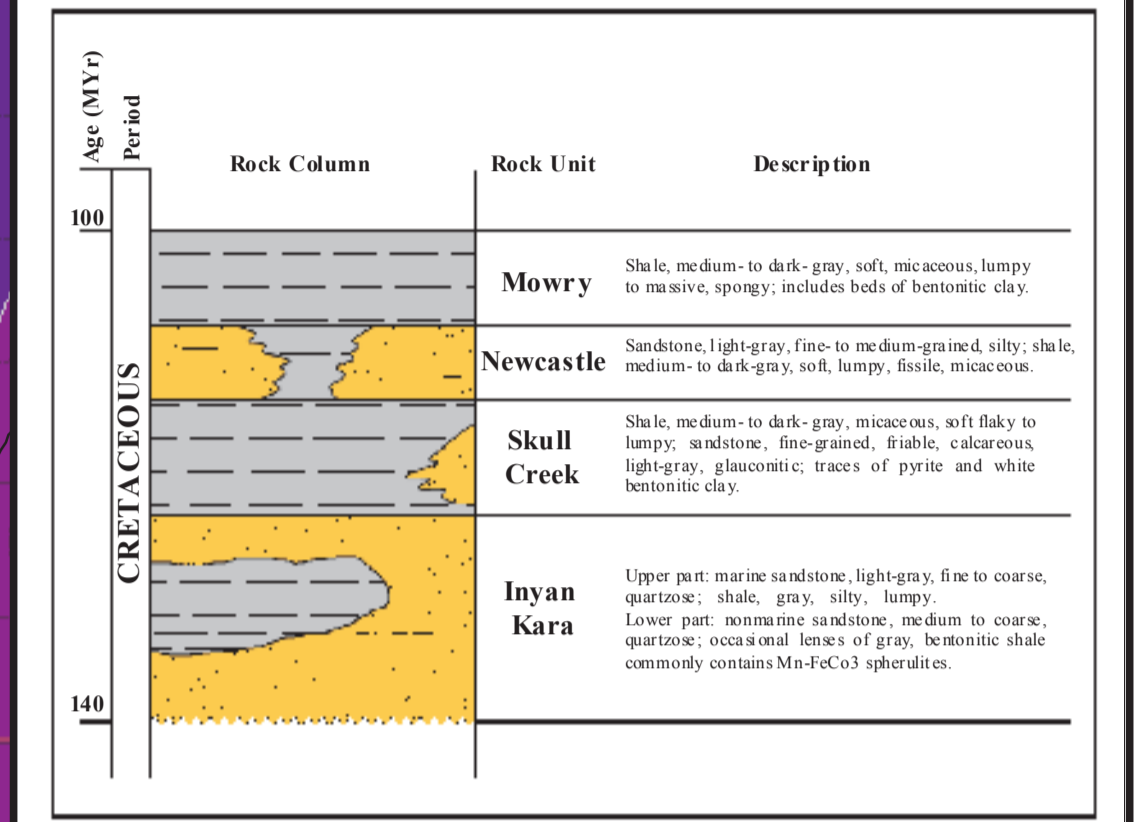


Figure 1. Generalized stratigraphy of the Dakota Group.

There are no reliable data sets for North Dakota that either list, or enable determination by extrapolation, subsurface temperatures for Cretaceous rocks. Bottom hole temperatures from oil well logs are unreliable and to assume that a simple linear relationship exists between temperature and depth would be incorrect. Although grossly linear the geothermal gradient in the upper lithosphere is significantly affected by thermal variables (heat flow and thermal conductivity) in the earth's crust. Any method used to accurately calculate subsurface temperatures must therefore take these factors into account. Provided the subsurface stratigraphy is known, Gosnold (1984) showed that at a given depth (Z) the temperature (T) can be represented by the following equation:

$$T = T_s + \sum_{i=1}^n \frac{Z_i(Q_i/K_i)}$$

Where:

- T_s = Surface temperature (in °C)
- Z_i = Thickness of the overlying rock layer (in meters)
- K_i = Thermal conductivity of the overlying rock layer
- n = Number of overlying rock layers
- Q = Regional heat flow

For the data set used to produce this map T_s, K and Q were assumed to be constants. Mean surface temperature (T_s = 5.1° C [41° F]) was calculated from monthly station normals (at Bismarck Municipal Airport, Fargo Hector Airport, Grand Forks International Airport, and Williston Stoulin Airport) for the period 1971 to 2000 (http://cdo.nd.gov/climate_normals/clim81/NDnorm.pdf).

Thermal conductivities (K) for formations overlying the Inyan Kara are shown in Table 1.

Formation	Thermal Conductivity (W/M K)
Late Cretaceous, Paleogene and Neogene clays, silts and sands	1.7
Pierre	1.2
Greenhorn	1.2
Mowry, Newcastle, Skull Creek	1.2

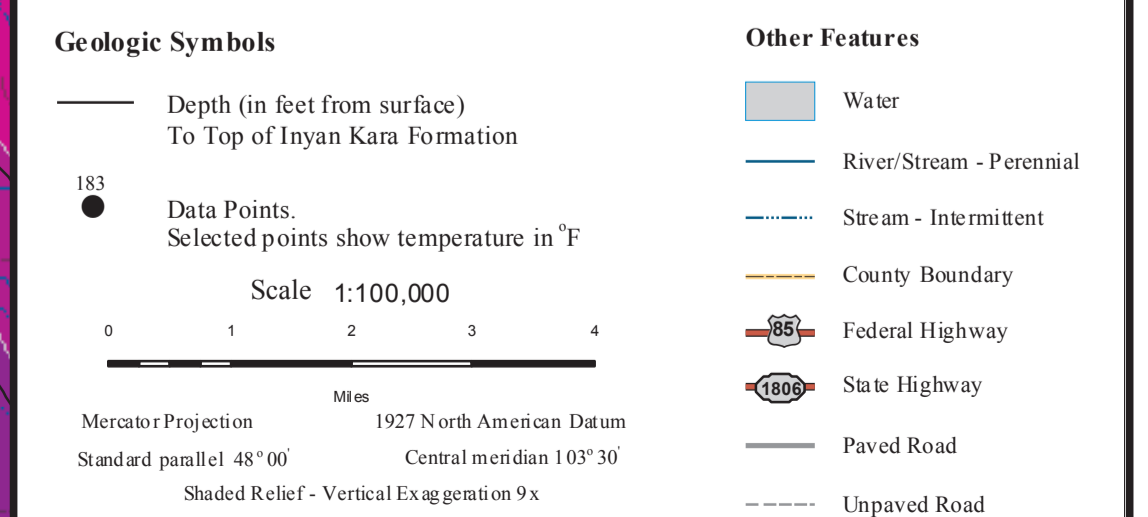
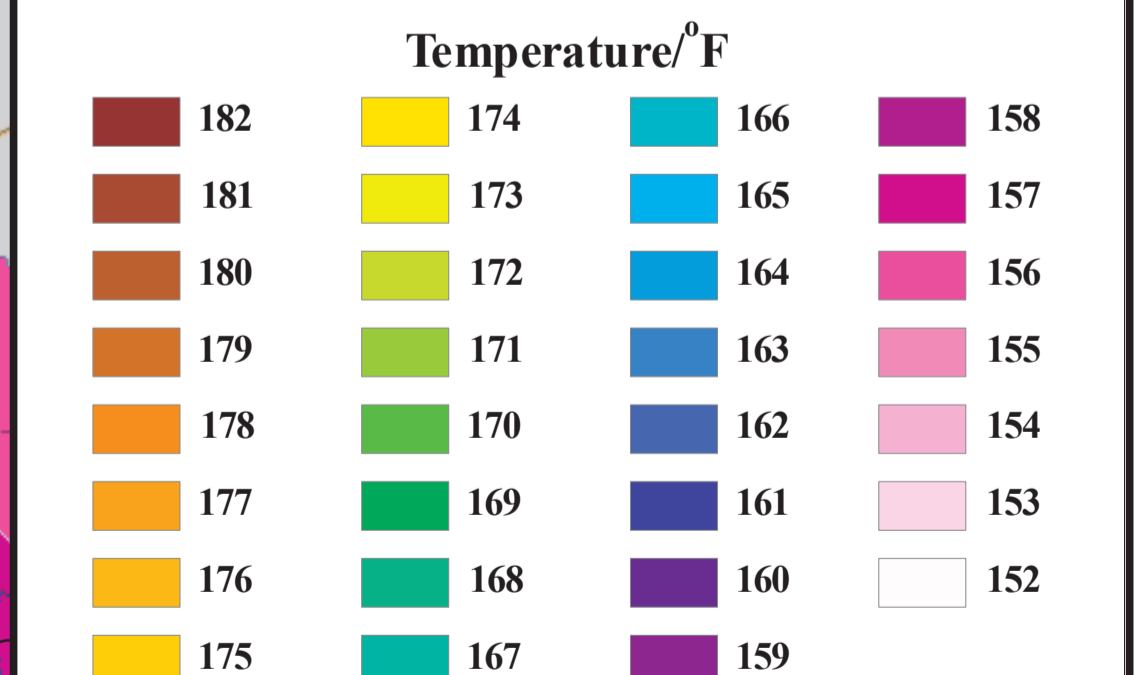
Table 1. Thermal conductivity estimates from Gosnold (1984)

Regional heat flow (Q = 62 mW/m²) was averaged from statewide data.

Rock units and thicknesses were obtained from oil well log tops (July 2006 update). Temperatures were only calculated for wells where all relevant log tops were given since omissions (particularly for the Pierre Formation) do not necessarily imply that units are absent.

Metadata used in the compilation of this map is available on CD.

References
Gosnold, W.D. Jr., 1984. Geothermal Resource Assessment for North Dakota. Final Report. U.S. Department of Energy Bulletin No. 84-04-MMRRI-04.



Note: This map was expanded beyond the normal Williston 100K Sheet to include an additional width of two miles to the Montana border.

