North Dakota Geological Survey
100K Series: WIst - g - MM

Deep Geothermal Resources: Estimated Temperatures at the Top of the Madison Group

Williston 100K Sheet, North Dakota

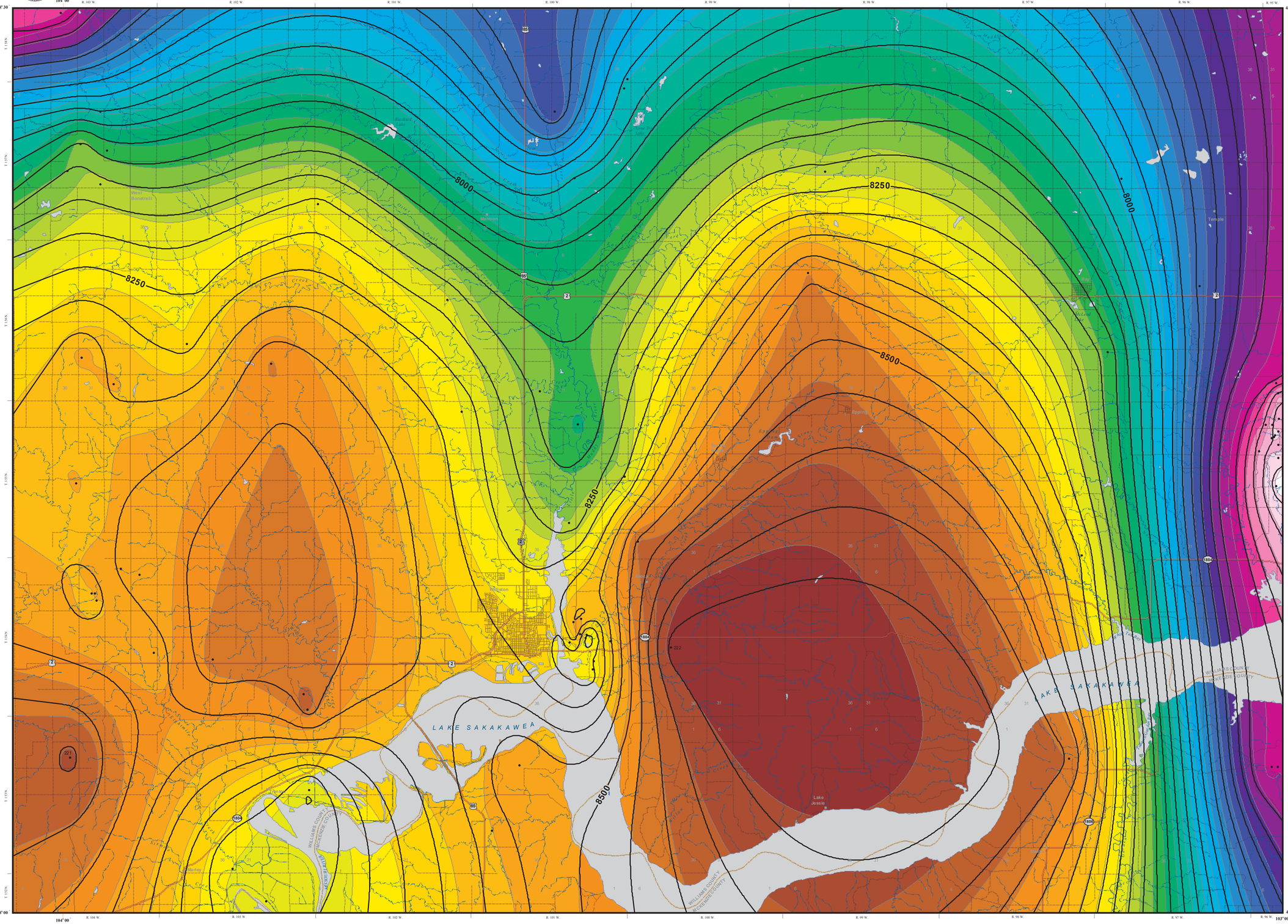
Edward C. Murphy, State Geologist
Lynn D. Helms, Director Dept. of Mineral Resources

Williston 100K Sheet, North Dakota

Adjoining 100K Maps

Plentywood	Crosby	Kenmare
Culbertson		Stanley
Sidney	Watford City	Parshall

1983 Magnetic North Declination at Center of Sheet



Lorraine A. Manz
2007

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 Madison Group contains the second shallowest of four major geothermal aquifers that occur in the Williston Basin in North Dakota. The map shows calculated temperatures (T) for the top of the Madison Group (assumed in this study to be equivalent to the base of the Lodgepole Formation).

There are no data sets for North Dakota that list accurate temperatures for Paleozoic 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:

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

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 Sloulin Airport) for the period 1971 to 2000 (http://cdo.ncdc.noaa.gov/climatenormals/clim81/NDnorm.pdf). Thermal conductivities (K) for formations overlying the base of the Madison Group 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
Inyan Kara	1.6
Jurassic rocks	2.8
Spearfish	3.1
Minnekahta, Opeche	2.8
Minnelusa Group	3.2
Mississippian rocks above the Madison Unconformity	3.0
Madison Group	3.0

Table 1: Thermal conductivity estimates from Gosnold (1984)

Regional heat flow (Q= 62 mW/m^2) 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 commissions (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.

Temperature/°F

222	214	206	198
221	213	205	197
220	212	204	196
219	211	203	195
218	210	202	194
217	209	201	193
216	208	200	
215	207	199	

Geologic Symbols

Depth (in feet from surface) To Top of Madison Group

221 Data Points. Selected points show temperature in °F

Scale 1:100,000

0 1 2 3 4 Miles

Mercator Projection — 1927 North American Datum
Standard parallel 48° 00' — Central meridian 103° 30'
Shaded Relief - Vertical Exaggeration 9x

Other Features

Water
River/Stream - Perennial
Stream - Intermittent
County Boundary
85 Federal Highway
1804 State Highway
Paved Road
Unpaved Road

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

Cartographic Compilation: Elroy L. Kadrmas