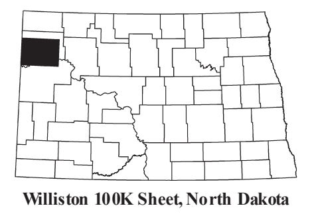
North Dakota Geological Survey
100K Series: Wlst - g - Dd

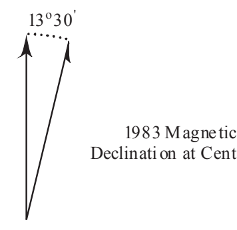

Williston 100K Sheet, North Dakota

Deep Geothermal Resources: Estimated Temperatures at the Top of the Duperow Formation

Williston 100K Sheet, North Dakota

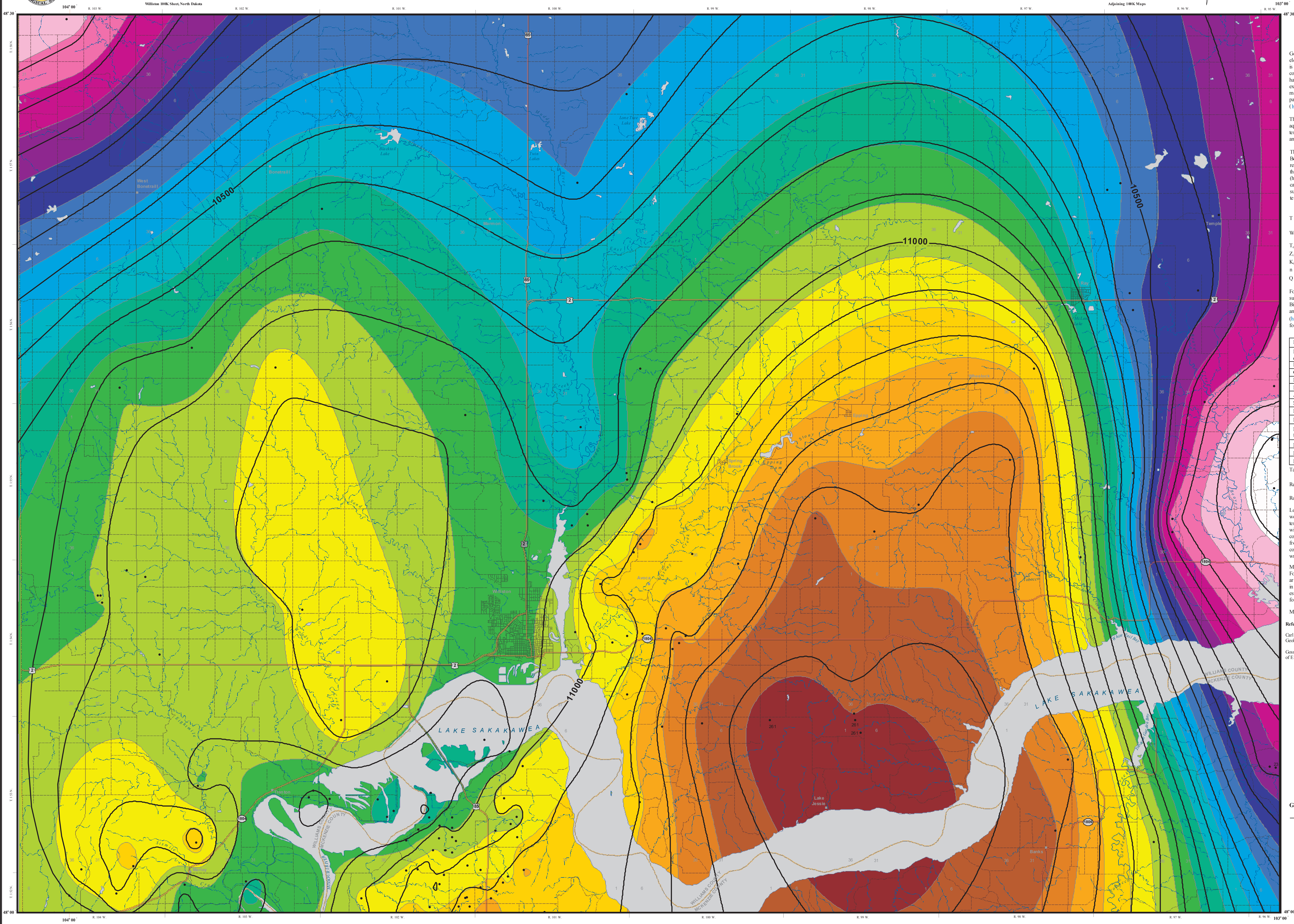
Plentywood	Crosby	Kenmare
Culbertson		Stanley
Sidney	Watford City	Parshall

Adjoining 100K Maps



1983 Magnetic North
Declination at Center of Sheet

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



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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 Devonian-age Duperow Formation contains the second deepest of four major geothermal aquifers that occur in the Williston Basin in North Dakota. The map shows calculated temperatures (°F) for the top of the Duperow Formation below the city of Williston and the surrounding area.

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:

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

Where:

T_o = 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_0, K and Q were assumed to be constants. Mean surface temperature(T_0 = 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 Duperow Formation 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
Bakken	1.5
Duperow	3.5

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).

Logtops are seldom picked for all formations in the stratigraphic column, particularly for deep wells. In this study, however, this is not a concern because thermal conductivities, and therefore temperature gradients, do not change significantly in similar lithologies. Thus, only formations with potential for producing thermal water or those that have a markedly different thermal conductivity to the overlying rocks need to be identified. Measured temperature-depth profiles from wells in the Williston Basin versus a modeled profile based on the stratigraphy and thermal conductivity in the central part of the basin show this assumption to be valid (W.D. Gosnold, written commun., 2007).

Most of the wells that extend below the Madison do not show a pick for the top of the Pierre Formation. This omission, if not corrected, would lead to calculated subsurface temperatures that are too low. The relatively small data set comprising wells for which complete stratigraphic information is available down to the Duperow Formation was thus supplemented by estimating the depth to the top of the Pierre using Carlson's structure map (1982) and wells for which the required logtops were otherwise given.

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

References

Carlson, C.G., 1982, Structure Map on Top of the Cretaceous Pierre Formation in North Dakota: North Dakota Geological Survey Miscellaneous Map No. 23.

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

🟥 260	🟨 250	🟦 240	🟪 230
🟫 258	🟩 248	🟦 238	🟪 228
🟧 256	🟩 246	🟦 236	⬜ 226
🟧 254	🟩 244	🟪 234	
🟨 252	🟦 242	🟪 232	

Geologic Symbols

— Depth (in feet from surface) To Top of Duperow Formation

261 ● 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
1806	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