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Deep Geothermal Resources: Estimated Temperature on Top of the Lodgepole Formation

Cedar Hills Field, Bowman/Slope Counties, North Dakota

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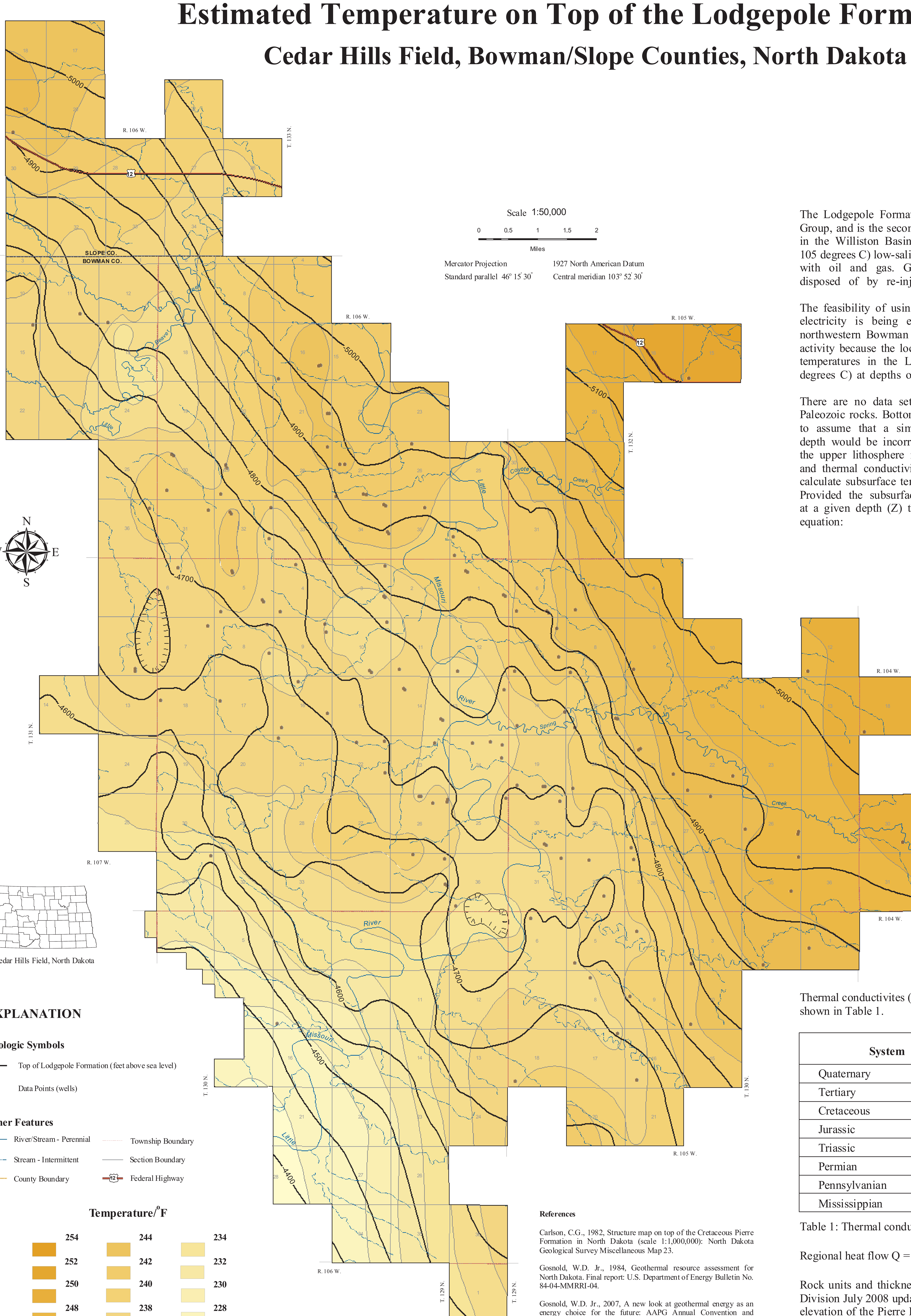

Cedar Hills Field, North Dakota

The Lodgepole Formation is the basal unit of the Mississippian-age Madison Group, and is the second shallowest of four major geothermal aquifers that occur in the Williston Basin. In southwestern North Dakota hot (> 220 degrees F, 105 degrees C) low-salinity waters from the Lodgepole Formation are co-produced with oil and gas. Generally regarded as waste, these fluids are usually disposed of by re-injection into the subsurface.

The feasibility of using geothermal waters from oil and gas wells to generate electricity is being explored in North Dakota. The Cedar Hills field in northwestern Bowman County and southwestern Slope County is one focus of activity because the local heat flow is one of the highest in the state, producing temperatures in the Lodgepole Formation in excess of 250 degrees F (120 degrees C) at depths of less than 10,000 feet.

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 exits 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 layers (in meters)
K_i = Thermal conductivity of the overlying rock layer
n = Number of overlying rock layers
Q = Regional Heat Flow

For the data used to produce this map T_o, K and Q were assumed to be constants. Mean surface temperature ($T_o = 5.1^o$ C [41^o 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 conductivites (K) for formations overlying the Lodgepole Formation are shown in Table 1.

System	Thermal Conductivity (W/m K)
Quaternary	1.4
Tertiary	1.2
Cretaceous	1.2
Jurassic	1.3
Triassic	1.3
Permian	2.9
Pennsylvanian	1.7
Mississippian	2.9

Table 1: Thermal conductivity estimates from Gosnold (2007)

Regional heat flow Q = 65 mW/m^2 (Gosnold, 1984).

Rock units and thicknesses were obtained from oil well log tops (ND Oil & Gas Division July 2008 update). Carlson's structure map (1982) was used to estimate the elevation of the Pierre Formation where there was no pick. The map was compiled using approximately 320 data points (wells).

EXPLANATION

Geologic Symbols

Top of Lodgepole Formation (feet above sea level)

Data Points (wells)

Other Features

River/Stream - Perennial
Stream - Intermittent
County Boundary
Township Boundary
Section Boundary
Federal Highway

Temperature/°F

254
252
250
248
246
244
244
242
240
238
236
234
234
232
230
228
226
224

References

Carlson, C.G., 1982, Structure map on top of the Cretaceous Pierre Formation in North Dakota (scale 1:1,000,000): North Dakota Geological Survey Miscellaneous Map 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.

Gosnold, W.D. Jr., 2007, A new look at geothermal energy as an energy choice for the future: AAPG Annual Convention and Exhibition, Long Beach, Calif., 2007.

Cartographic Compilation: Elroy L. Kadrmas