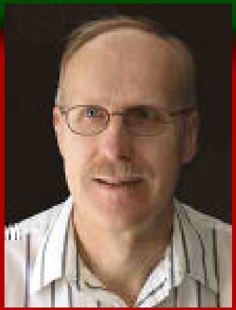
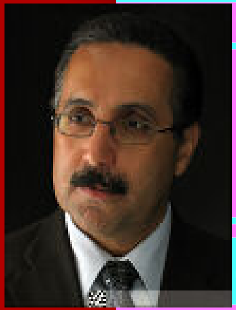
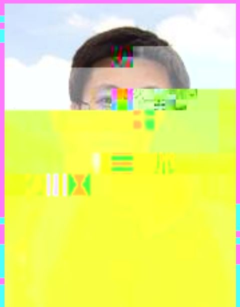
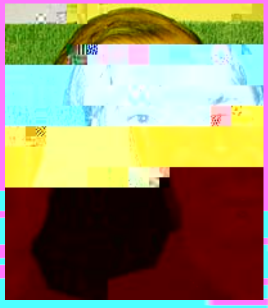
The University of North

A Remarkable Effort to Test the Concept of Electrical Power Generation from Co-Produced Oil Field Geothermal Waters









Southern Methodist University
Dallas, TX

Outline

150 °C to 90 °C ND and SD basins

- USGS Circular 893: The principal water producing formations, the Dakota Group and the Madison aquifer contain 2,050 EJ.
- Analysis of all potential aquifers in South Dakota and North Dakota indicates that the total accessible resource base in the two basins is approximately 33,700 EJ.
- The MIT report used the Circular 893 numbers and estimated the US resource base as 100,000 EJ.

Binary Turbine Development

- xperimental rogram to timulate ompetitive esearch

5. Make, model, and projected net power production of the proposed power plant;
6. Proposed power cycle including but not limited to process schematic2 with stream state points at inlet and outlet of major components;
7. Handling and disposal of power plant working fluid;
8. Plans for water treatment and cleaning of scaled or fouled surfaces; and
9. Nature of cooling water supply (if used).

Actual characteristics of each well or separator that is proposed as a source of geothermal fluid, including:

10. Temperature;
11. Flow rate;
12. Quantitative analysis of produced fluids, including chemical analyses of water cuts and oil /natural gas;
13. Formation and depth from which the fluid is produced;
14. Modifications to the wellhead and/or surface systems, if necessary

(existing production and injection wells must be able to be re-entered without conducting well maintenance operations at the time of application submittal);

including but not limited to:

1. Arrangements between leaseholders, developers, owners, operators, and/or others, including proof that all surface and/or subsurface rights including rights to utilize the geothermal resource and the oil and/or gas wells have been secured by the appropriate parties;
2. Proof of ability to provide the non-Federal share of project costs;
3. Status of regulatory and environmental permitting required for the project;
4. Arrangements for distribution/use of power including Power Purchase Agreement (PPA), if applicable;

including but not limited to:

- Plan for information dissemination and technology transfer (including but not limited to papers, web casts, site visits, press releases) to industry and others.

- ***University of North Dakota School of Engineering and Mines***
- , PhD, Professor of Geophysics and Chair of the Department of Geology and Geological Engineering Project PI.
- , PhD, Professor of and Chair of the Department of Chemical Engineering. Design the fluid handling system between the separator and the ORC system. Work with Dr. Zeng on all matters concerning the chemistry of the production and disposal fluids and the processing of any produced salts.
- , PhD, Professor of Electrical Engineering. Design the electrical power and work with WEPC engineers to link the ORC system with the power grid.
- , PhD, Assistant Professor of Petroleum Engineering in the Department of Geology and Geological Engineering. Fluid handling systems and design of technology for future tech transfer to other systems.
- , PhD, Chemical Engineering Research Associate. On-site engineer for all activities.

Project Partners

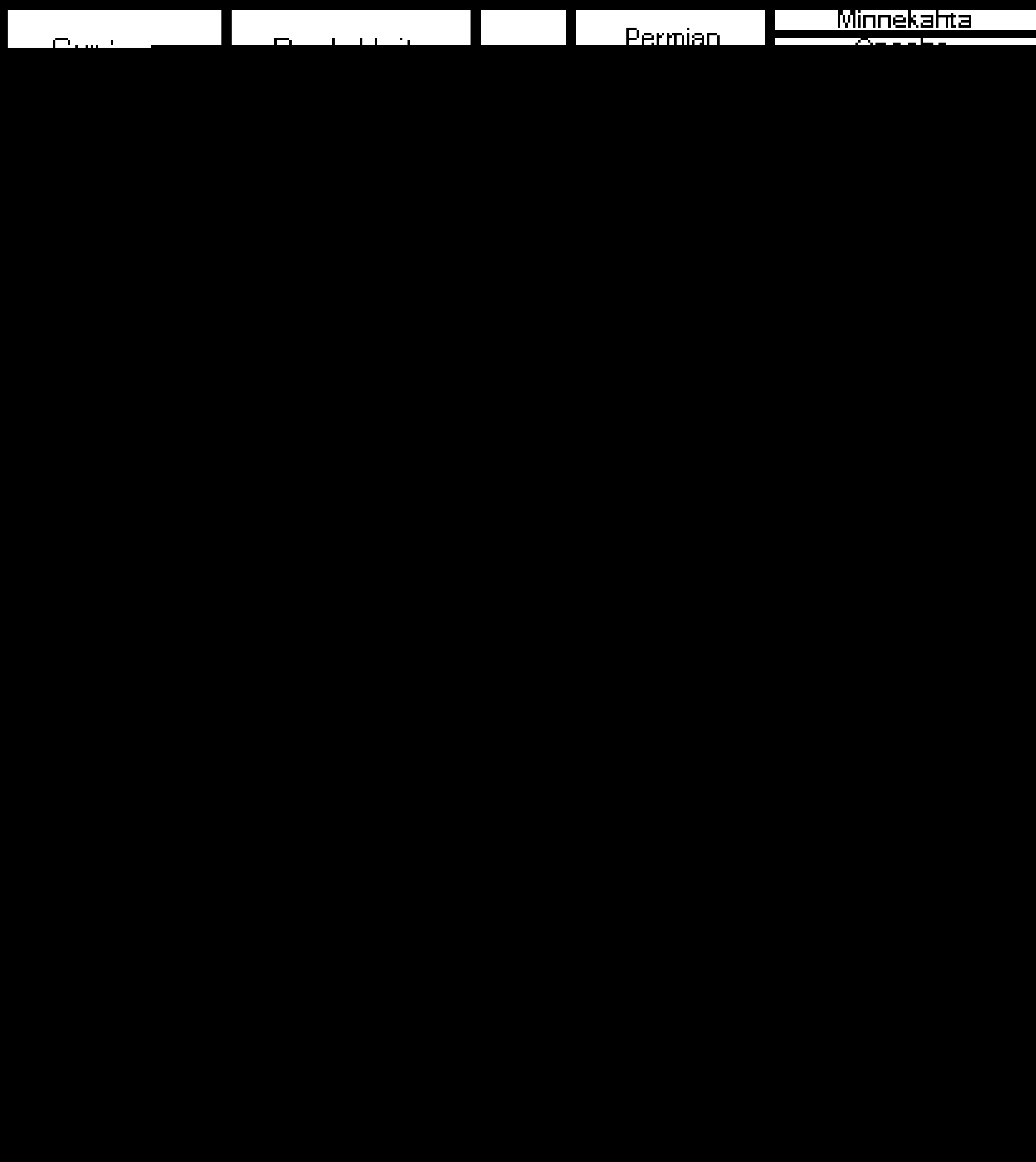
- ***North Dakota Geological Survey***
  - Lorraine Manz, PhD, North Dakota Geological Survey. Principal contact and administrator for the North Dakota geothermal regulatory program.
- ***Encore Acquisition Company***
  - Robert Sutherland, P.E., Management oversight for the oil field and all agreements and interactions among the four parties.
- ***West Plains Electric Cooperative, Basin Electric***
  - David C. Schelkoph, C.E.O., West Plains Electric Cooperative Inc. Management oversight for the link with the local electrical power grid and power purchase arrangements.
- ***UTC***
  - Halley Dickey, ORC power module

Objective 1

- ***Demonstrate the feasibility of adapting organic Rankine cycle (ORC) technology to generate electricity at economical rates using geothermal waters that are coproduced with oil and gas.***

Objective 3

- ***Establish a Center of Excellence in ORC-geothermal power to grow the human resource base for large scale development of geothermal energy.***



The production and reinjection unit is a reef system within the Lodgepole Fm (Miss).

Fm depth is between 2787 m (9142') to 3023 m (9918') below ground surface.

Formation temperature is 118 ºC (244 ºF) and produced water temperature at the surface is above 100 C.

The selected well currently produces approximately 11,500 bbl per day (400 gpm) of water.


DICKINSON - 2MI ------>
DICKINSON RESERVOIR
Map Features

Some Engineering Aspects

- Water chemistry
- Cooling cycle of the heat exchanger
- Fluid disposal
- A prototype water-cooled Ormat Energy Converter (OEC) estimated at 330 kW gross and 280 kW net.

Water Chemistry for Knopik #1-11 (NDGS 13715)

Cooling cycle of the heat exchanger

- During the winter months, the low ambient temperature of the air would be used to condense the turbine outlet vapor using banks of high finned tubes.
- During the summer months, plate heat exchangers would be used to transfer the heat to cooling water drawn from a bank of shallow tube wells sunk in the bed of the Heart River that flows about 1/2 mile south of the project site.

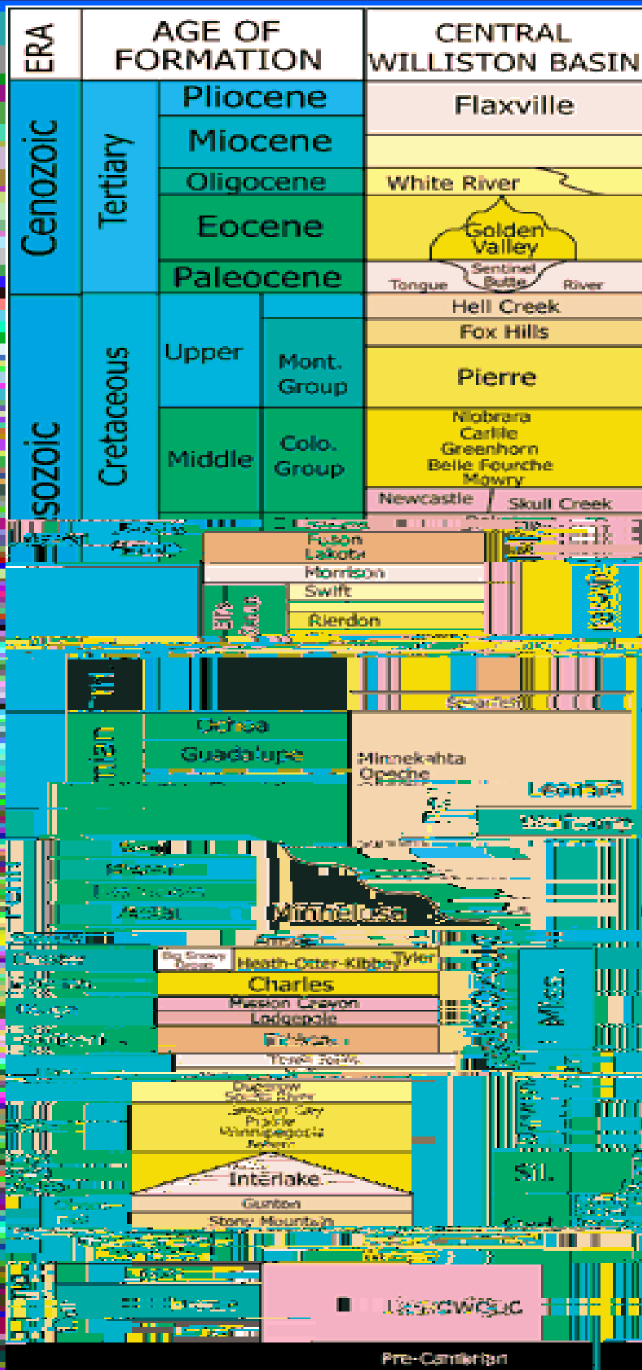
- Disposal of the geothermal fluids in three existing disposal wells in the Eland-Lodgepole field.
  - NDGS 13731 (1/2 miles)
  - NDGS 13819 (1/2 mile)
  - NDGS 13764 (1.5 miles)
- Fluid injection into Lodgepole formation.
- The combined injectivity of these three wells is 21,000 bbl/day and our requirement is 11,500 bbl/ day.

Williston Basin

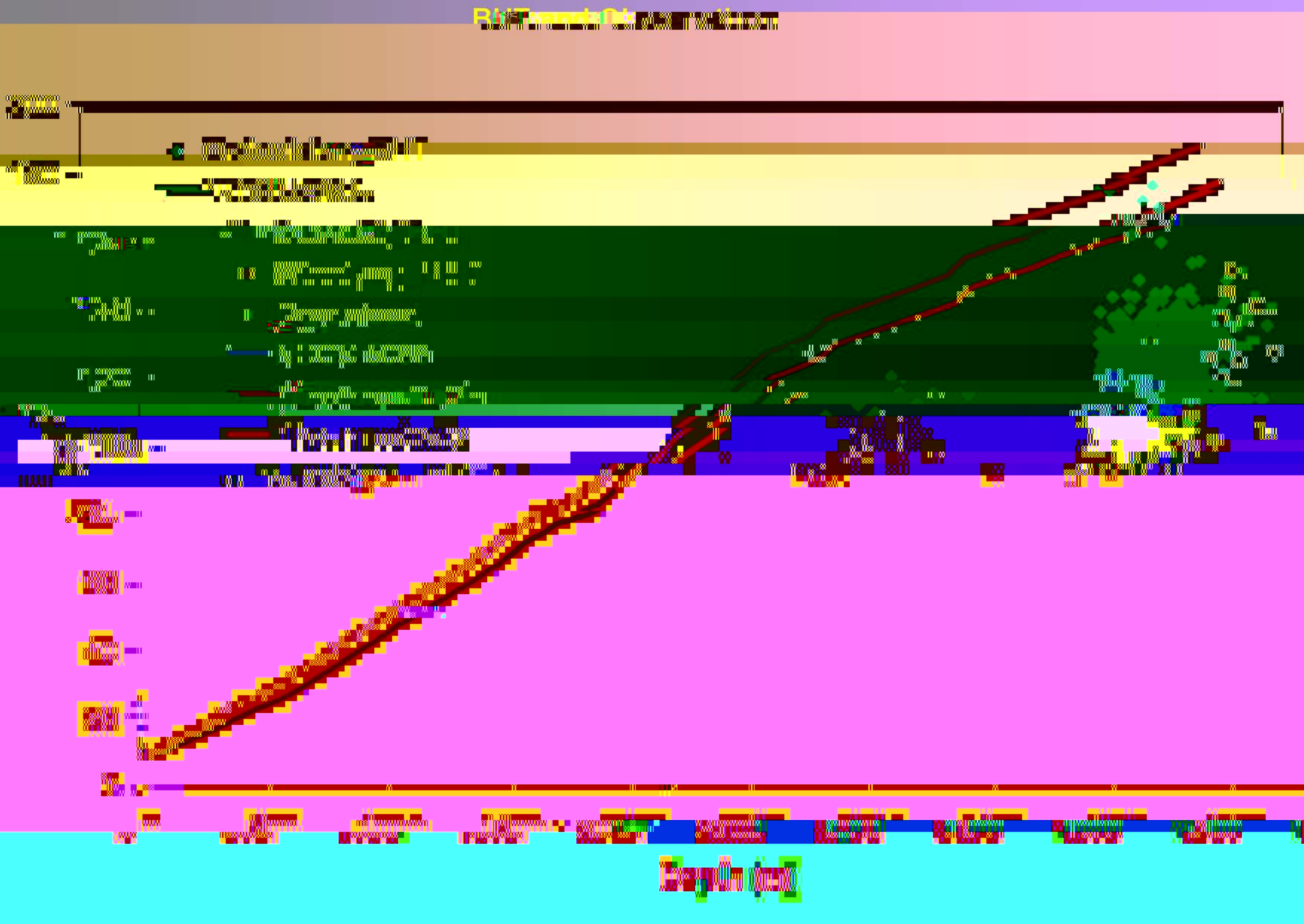
- 41 hydrocarbon producing formations, 39 produce oil and 2 produce nitrogen and methane.
- Total oil 1,602,055,219
- Total water 2,927,574,334

$$Q = \frac{dT}{dZ} K$$

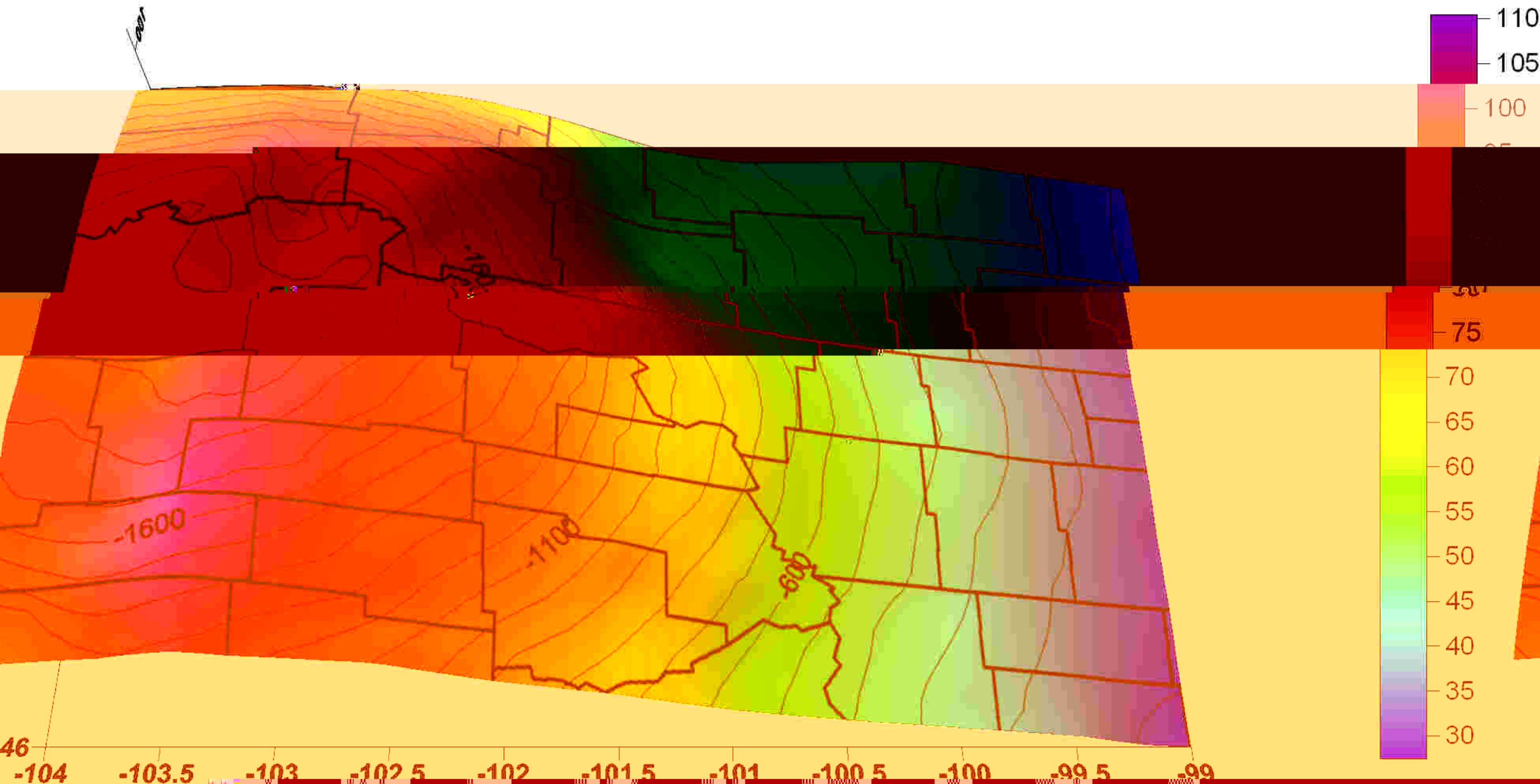
$$T \quad z \quad T \quad \frac{Z}{K} Tz$$ [illegible]


ERA
AGE OF FORMATION
CENTRAL WILLISTON BASIN
Cenozoic
Tertiary
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Flaxville
White River
Golden Valley
Sentinel Butte
Tongue
River
Cretaceous
Upper
Mont. Group
Middle
Colo. Group
Hell Creek
Fox Hills
Pierre
Niobrara
Carlile
Greenhorn
Belle Fourche
Mowry
Newcastle
Skull Creek
Morrison
Swift
Rierdon
Minnekahta
Opeche
Minnelusa
Heath-Otter-Kibbey
Tyler
Charles
Mission Canyon
Lodgepole
Interlake
Gunton
Stony Mountain
Sil.
Pre-Cambrian

Use the equilibrium temperature not the BHT



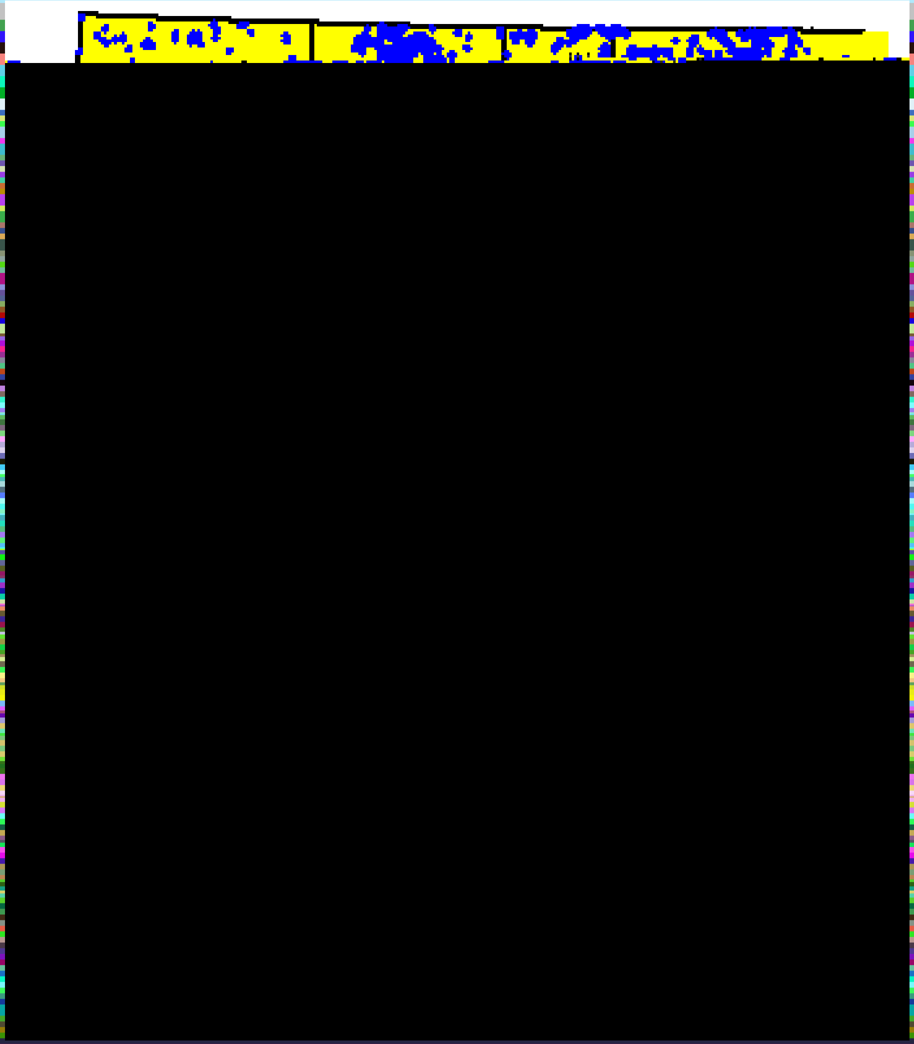
ρ



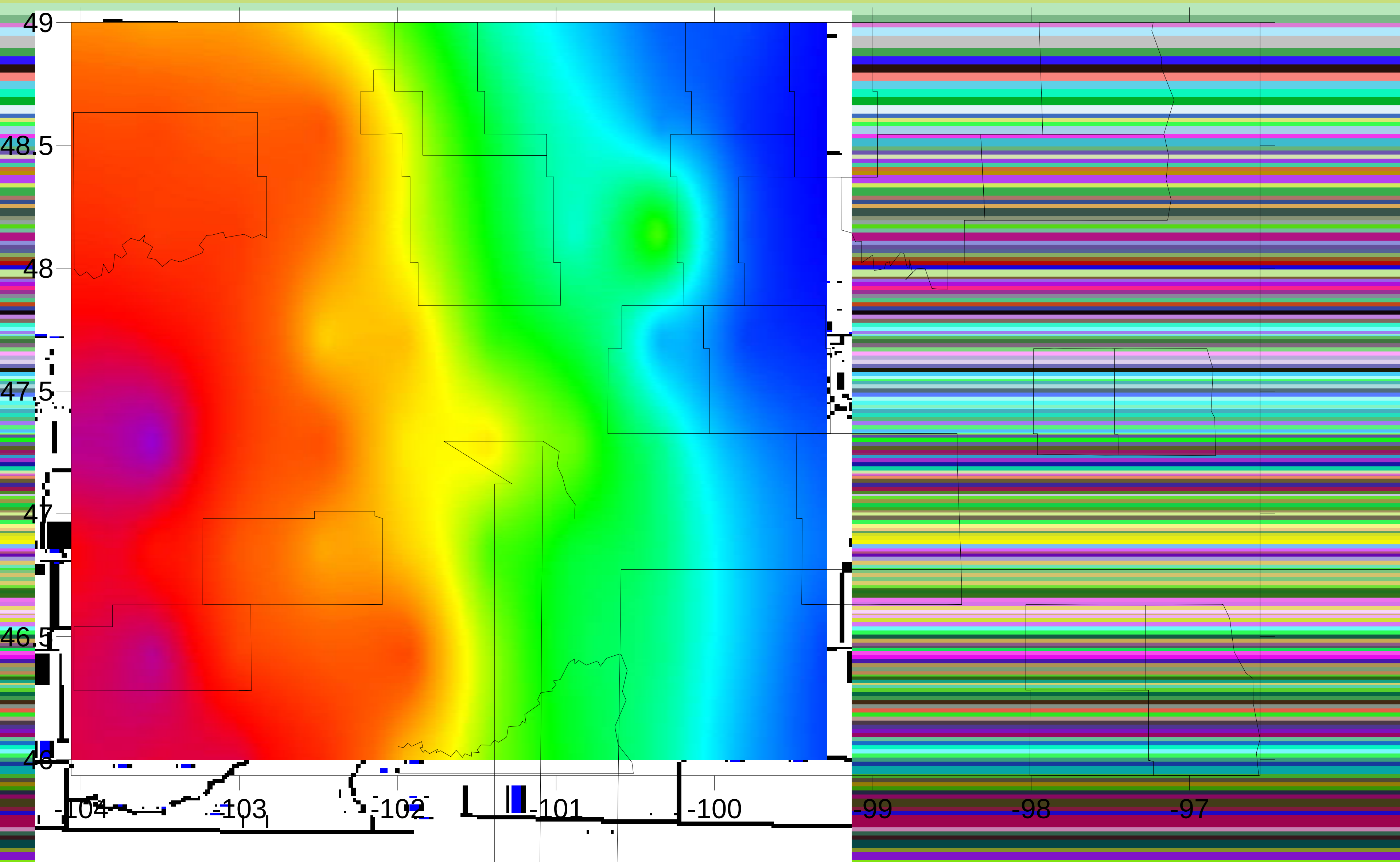
Colors are temperature, contours are depth (m), lines are county boundaries

FORMATION	BARRELS OF OIL	BARRELS OF WATER	MAX. TEMP C
Spearfish	582,601	320,626	120+
Spearfish/Madison/Charles	52,923,055	81,138,008	120+
Tyler	17,279,723	9,616,114	120+
Madison	1,003,859,751	2,266,631,018	132
Bakken (Sanish)	43,079,616	4,876,685	135+
Birdbear (Nisku)	16,532,269	19,875,577	135+
Duperow	48,360,560	51,290,164	135+
Souris River	58,090	61,886	140+
Dawson Bay	3,985,365	1,191,086	145+
Winnipegosis	8,853,724	6,663,034	145+
Interlake	62,397,829	140,808,361	145+
Stonewall	14,699,878	5,134,309	145+
Winnipegosis	8,853,724	6,663,034	145+
Red River	162,448,927	162,167,866	150+
Winnipeg/Deadwood	168,170	256,474	150+
Total	1,602,219,737	2,927,676,055	

ND oil producing counties

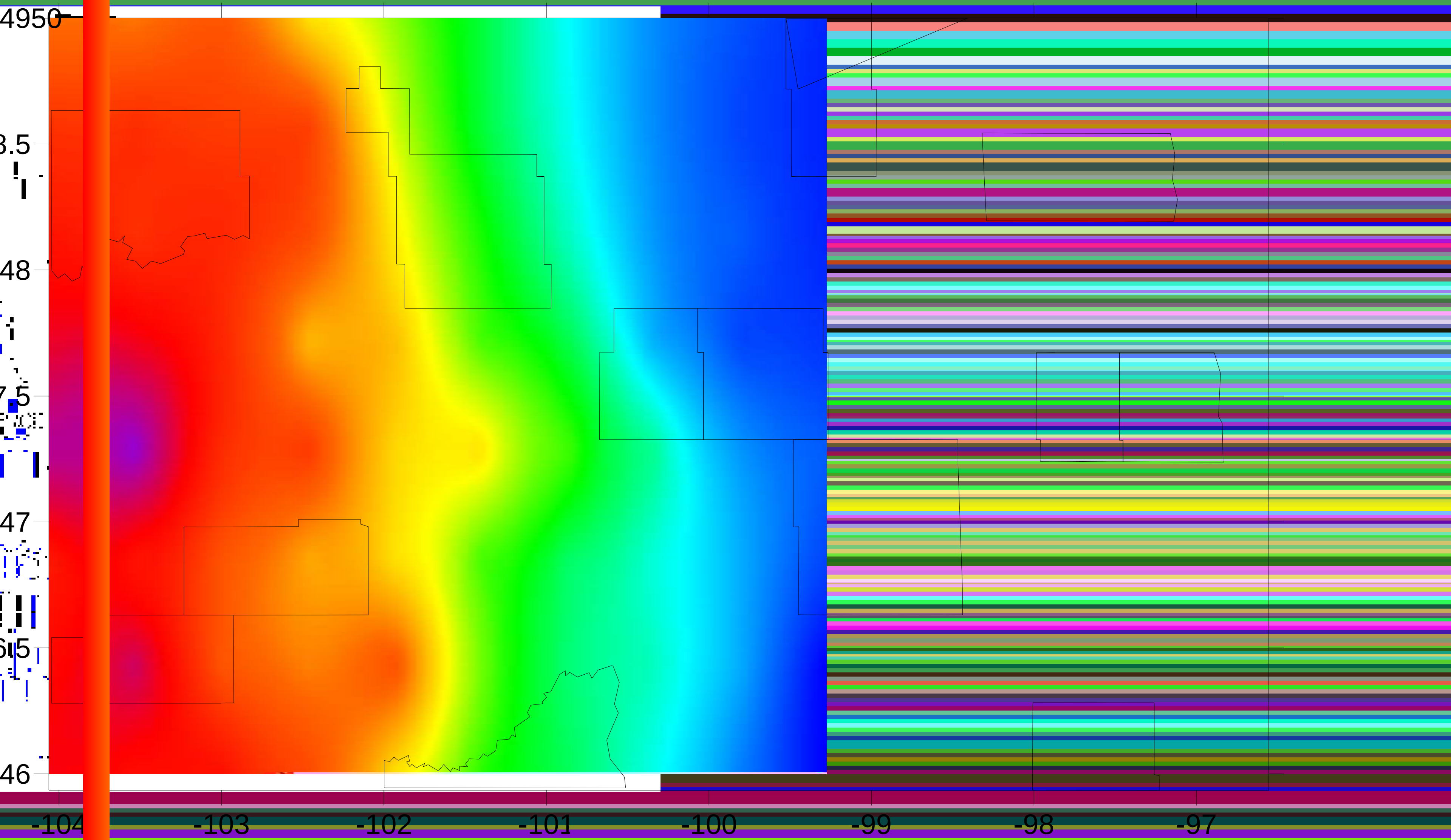


Duperow (Devonian)

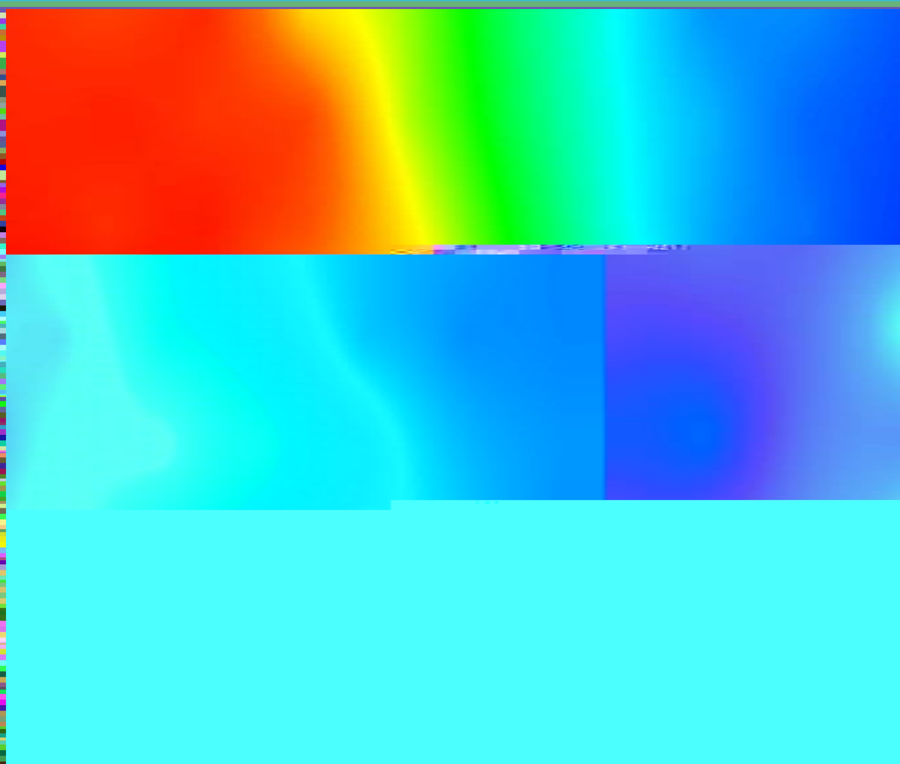


Red River Fm (Ordovician)

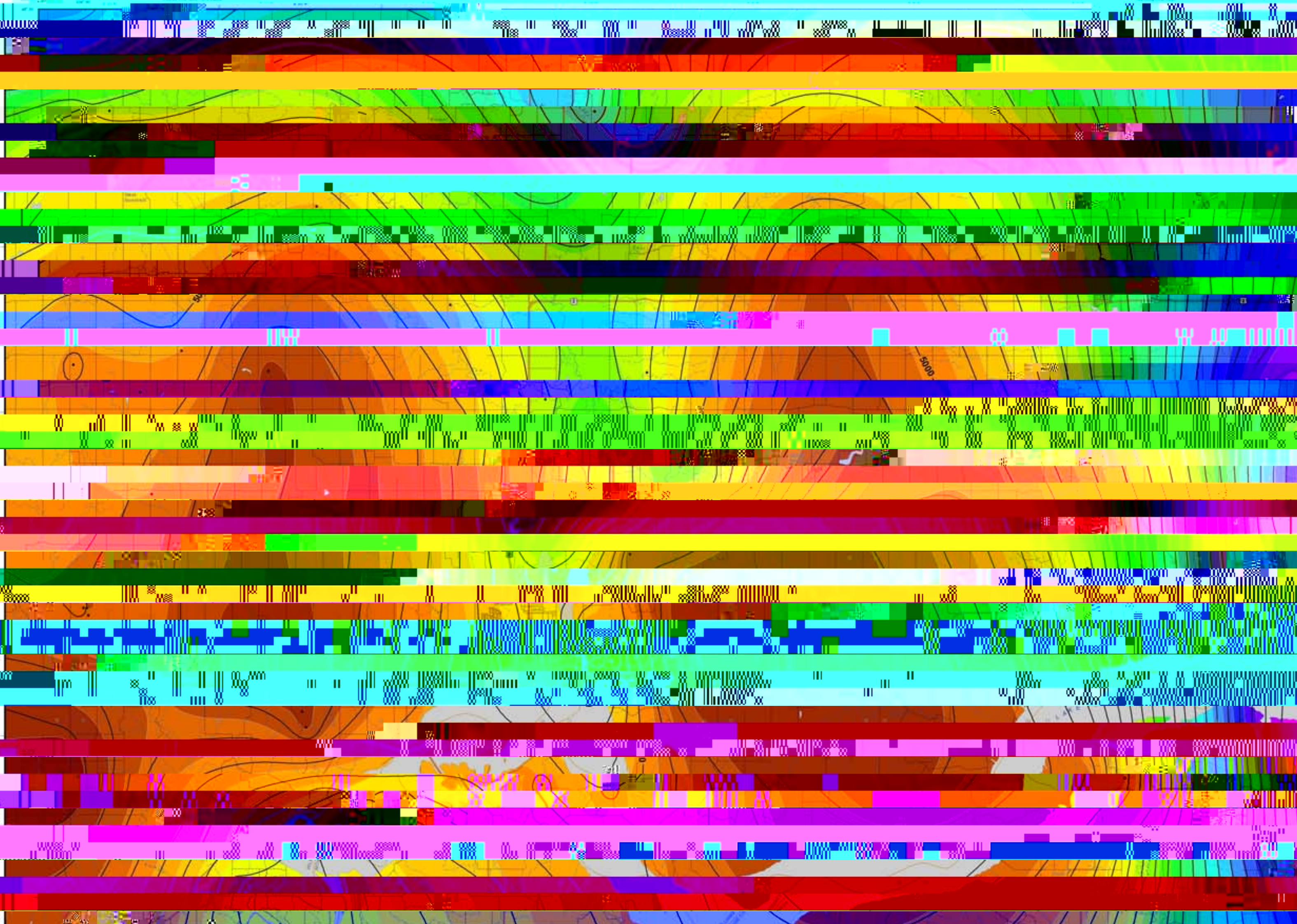
Maximum thickness 215 m



Deadwood Fm (Cambrian)



Deep Geot... Res... Esti...



...energy resources, particularly via existing oil and gas wells, is attracting a great deal of interest (http://www.und.edu/geothermal/).

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... relationship exists betwe... linear the geothermal gr...

Outcomes

Center of Excellence Application

- $3 million from State Dept. of Commerce
- $6 million from industry
- Seven objectives – one is development of electrical power from oil field waters

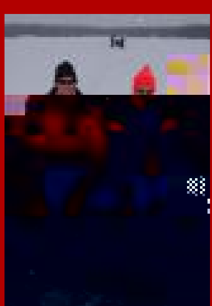
Minnesota Dept. Natural Resources

- EGS to meet requirement for power from renewable sources

Final Points

- Estimates of the energy that could be generated from co-produced U.S. oil field waste waters range from 4,590 to 21,933 MWe depending on the temperature of the resource.
- Development of existing capped and abandoned wells for water production can provide significant, sustainable, and environmentally sound power resource.

The University of North



"If you consider it a sport to gather your food by drilling through 8 inches of ice and sitting there all day hoping that the food will swim by, you might live in North Dakota." Jeff Foxworthy