Fluid Production for Geothermal Energy

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Some Acknowledgements…

Students

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Collaborators

- Steve Grasby
- Jennifer McIntosh

Roadmap

- The opportunity
- Potential for fluid production
- Challenges including the race for porosity

Albertans may face $8B bill for orphan wells unless rules change, lawyer says

Province 'hedging its bets' in case Supreme Court fails to put cleanup first, Keith Wilson says

By Rachel Ward, CBC News Posted: Nov 27, 2017 2:46 PM MT | Last Updated: Nov 28, 2017 10:00 AM MT

ALBERTA OIL
The Business of Energy

ENERGYINK

Alberta Government Eyes Geothermal Fix to Abandoned Well Crisis

AB considers converting disused wells to geothermal energy systems. Oil firm to coproduce oil and geothermal heat in Saskatchewan - two firsts for Canada.

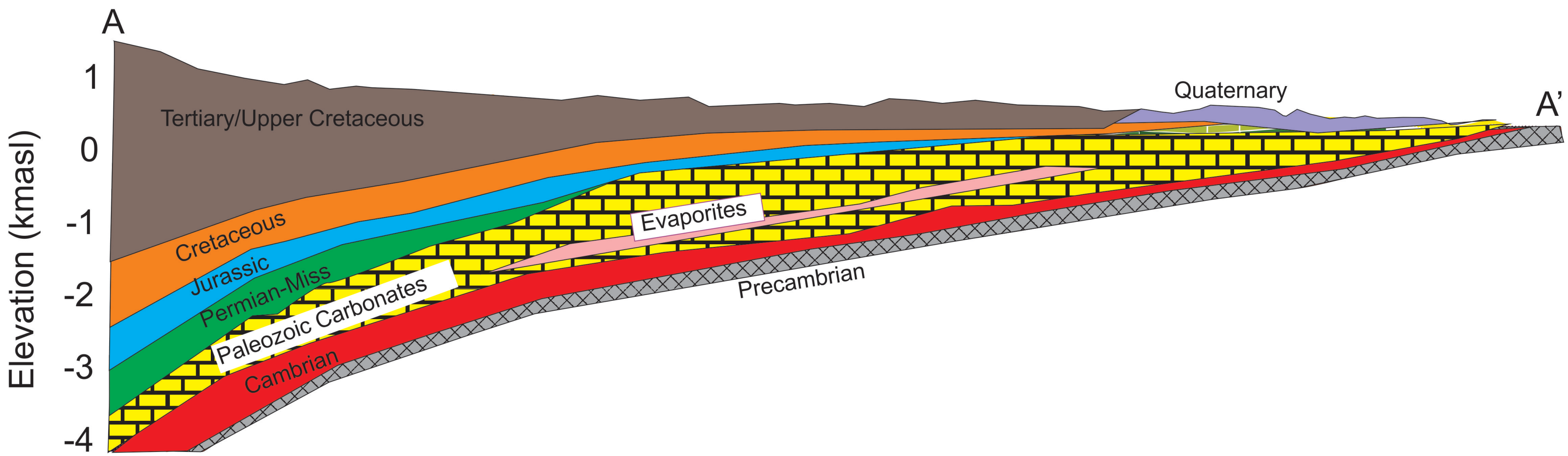
BY NICK WILSON

October 05, 2016

Alberta Energy may promote the conversion of disused oil and gas wells into geothermal systems as a partial solution to the province's abandoned well crisis.

"Using abandoned wells for geothermal is a complex issue that requires further input and consultation from a broad range of stakeholders," says Alberta energy minister Marg McCuaig-Boyd. "I have asked government staff to consider this option as we move forward with our climate plan and also in our considerations of the entire liability management system." A government official says the province aims to have policies in place before April, which may include tax and carbon credits.

The Western Canada Sedimentary Basin



Temperatures are known in the WCSB

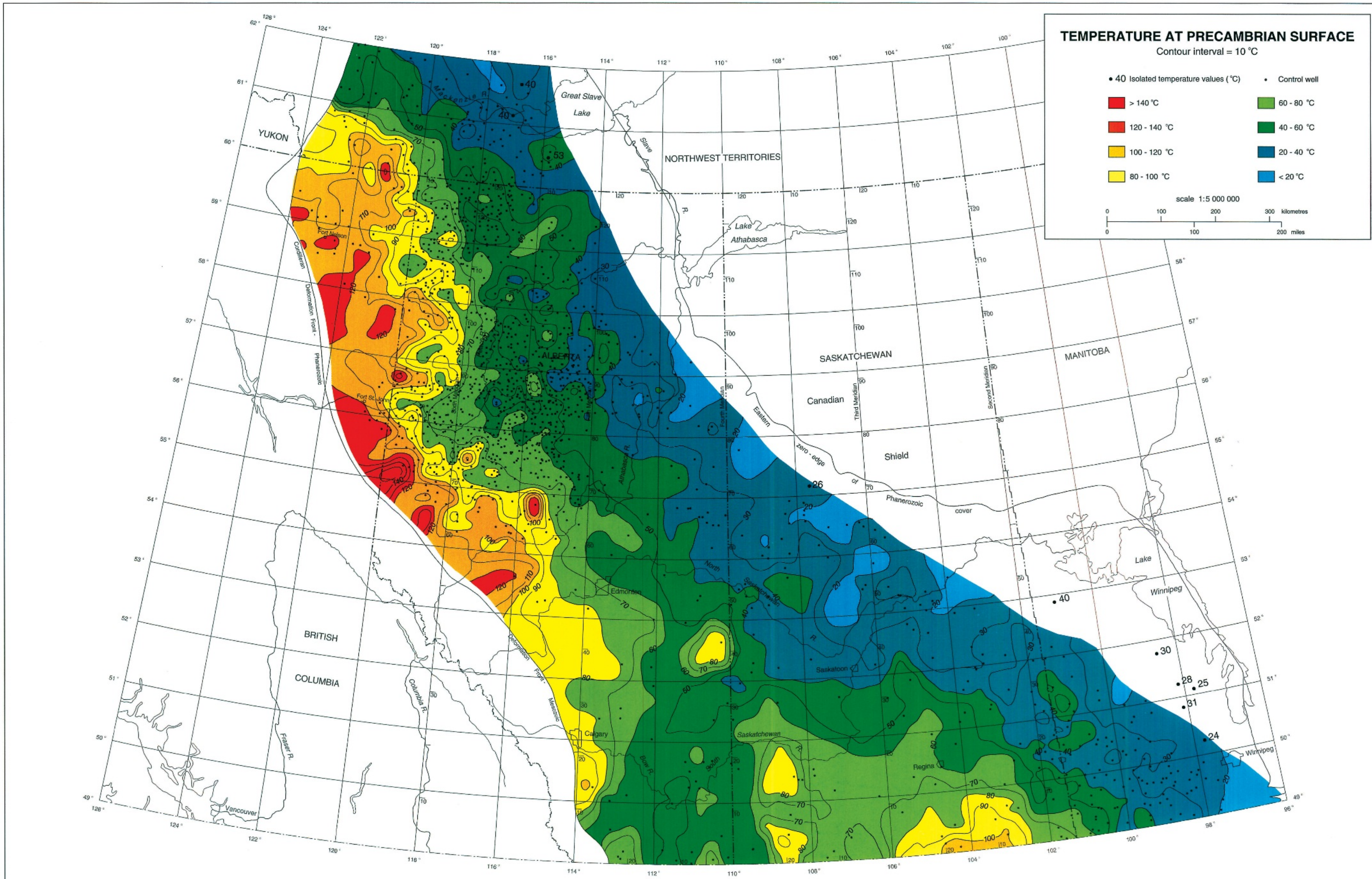


Figure 30.3 Temperature distribution (°C) at the base of the sedimentary column (top of Precambrian) in the Western Canada Sedimentary Basin. In the southeast (around Lake Winnipeg) and in the northeast (around Great Slave Lake), formation temperatures are represented as point values rather than isotherms because of anomalous values, data scarcity and edge effects, which do not allow for proper contouring.

Fourier's Law

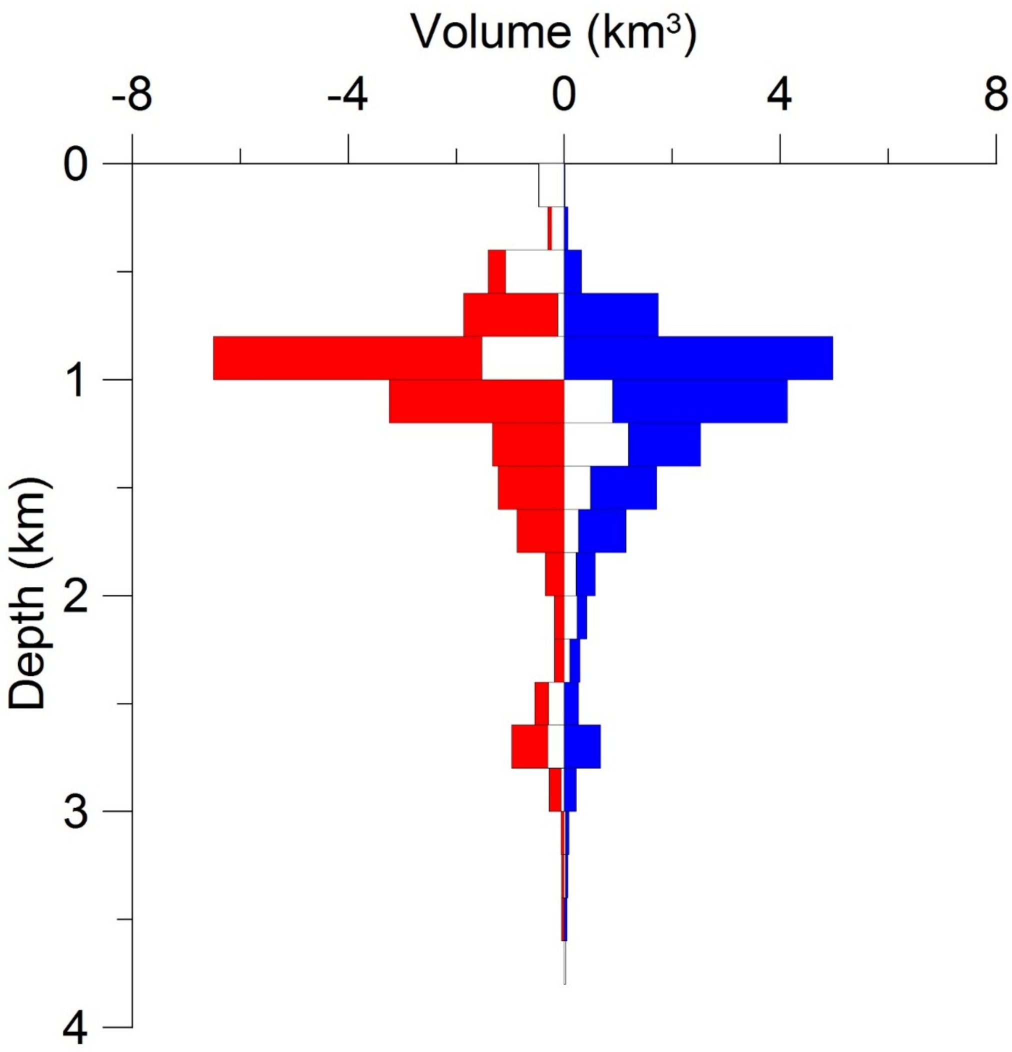
$$q_h = -\kappa \; dT/dx$$

Darcy's Law

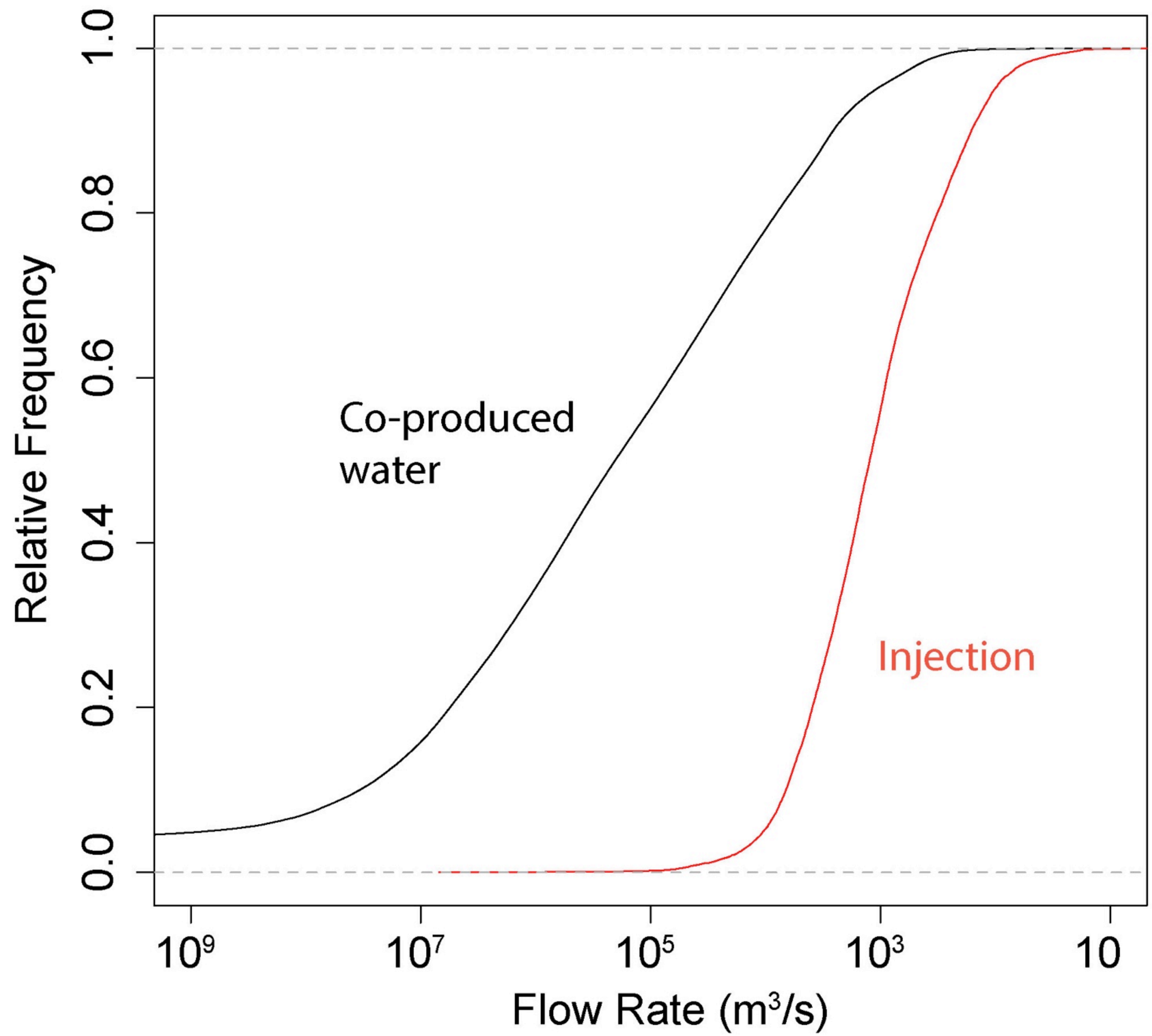
$$q_f = -K \; dh/dx$$

Over 20 billion m³ of water has been produced from the WSCB

Over 23 billion m³ of water has been injected into the WSCB



Injection wells operate at higher rates than production wells.



Direct-use for space heating is possible with at temperatures above 45°C [Rafferty, 2004; Lund, 2011], resulting in an outlet temperature of 30°C.

Based on these criteria, the thermal power associated with each well is estimated with the following equation:

$P_t = Q_f \rho_f c_f \Delta T$

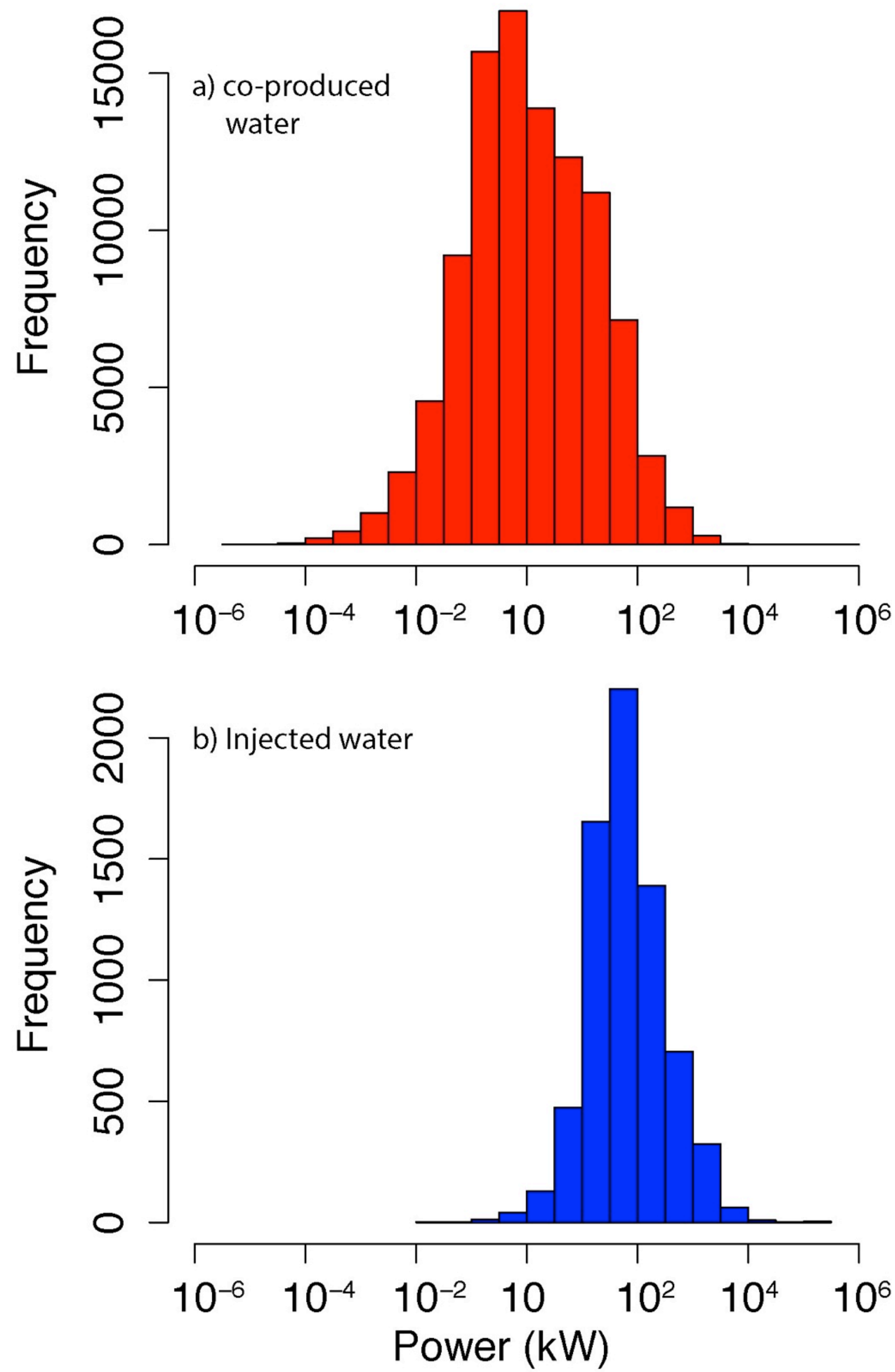
Where:

P_t is thermal power, Q_f is fluid flow rate, ρ_f is fluid density and c_f is fluid heat capacity.

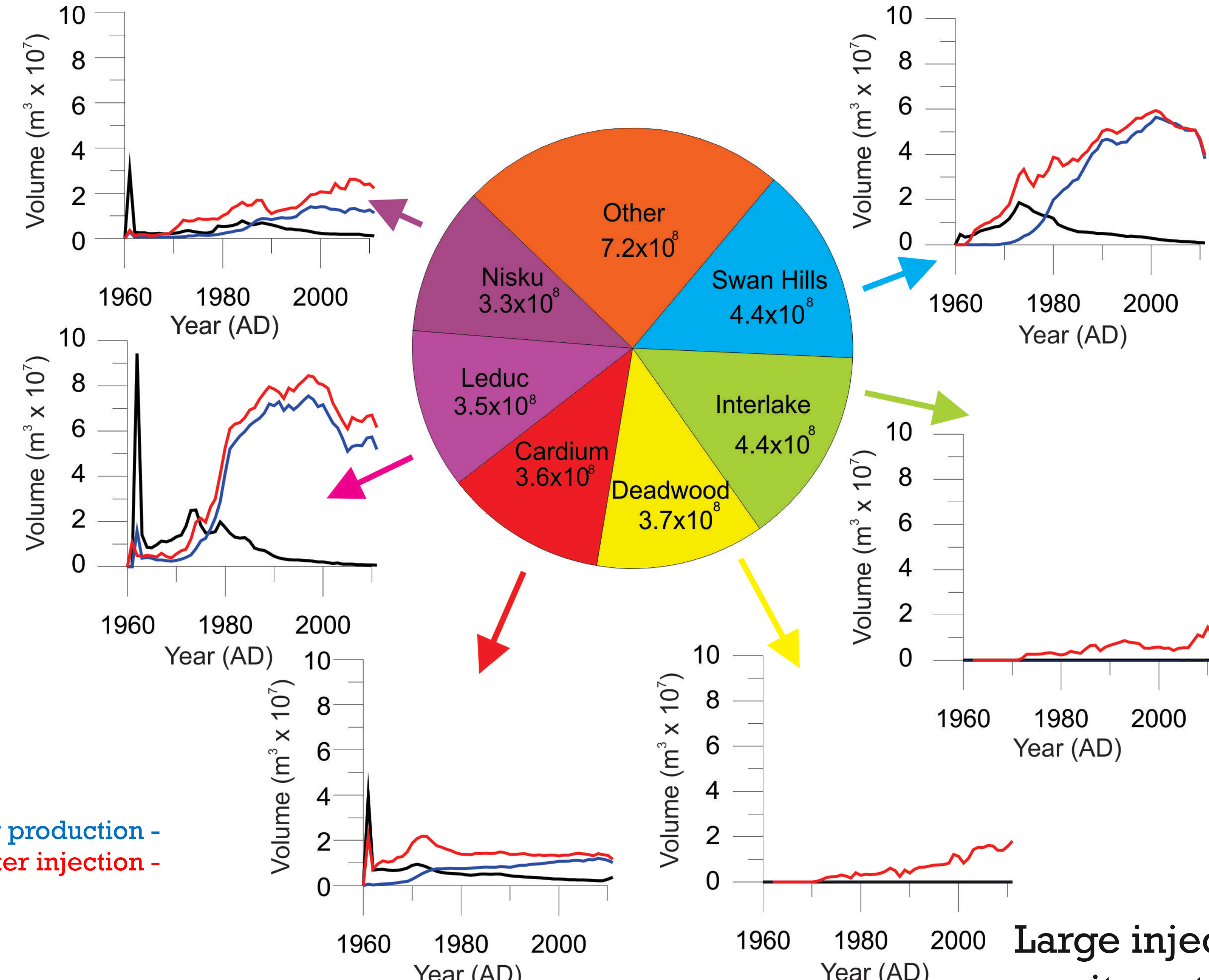
T is calculated assuming a geothermal gradient of 0.03 K/m

Most production wells do not produce sufficient amounts of water to be viable geothermal wells.

Roughly 50% of injection wells might be viable as geothermal wells (>100 kW_t). A few hundred would produce > 1 MW_t.

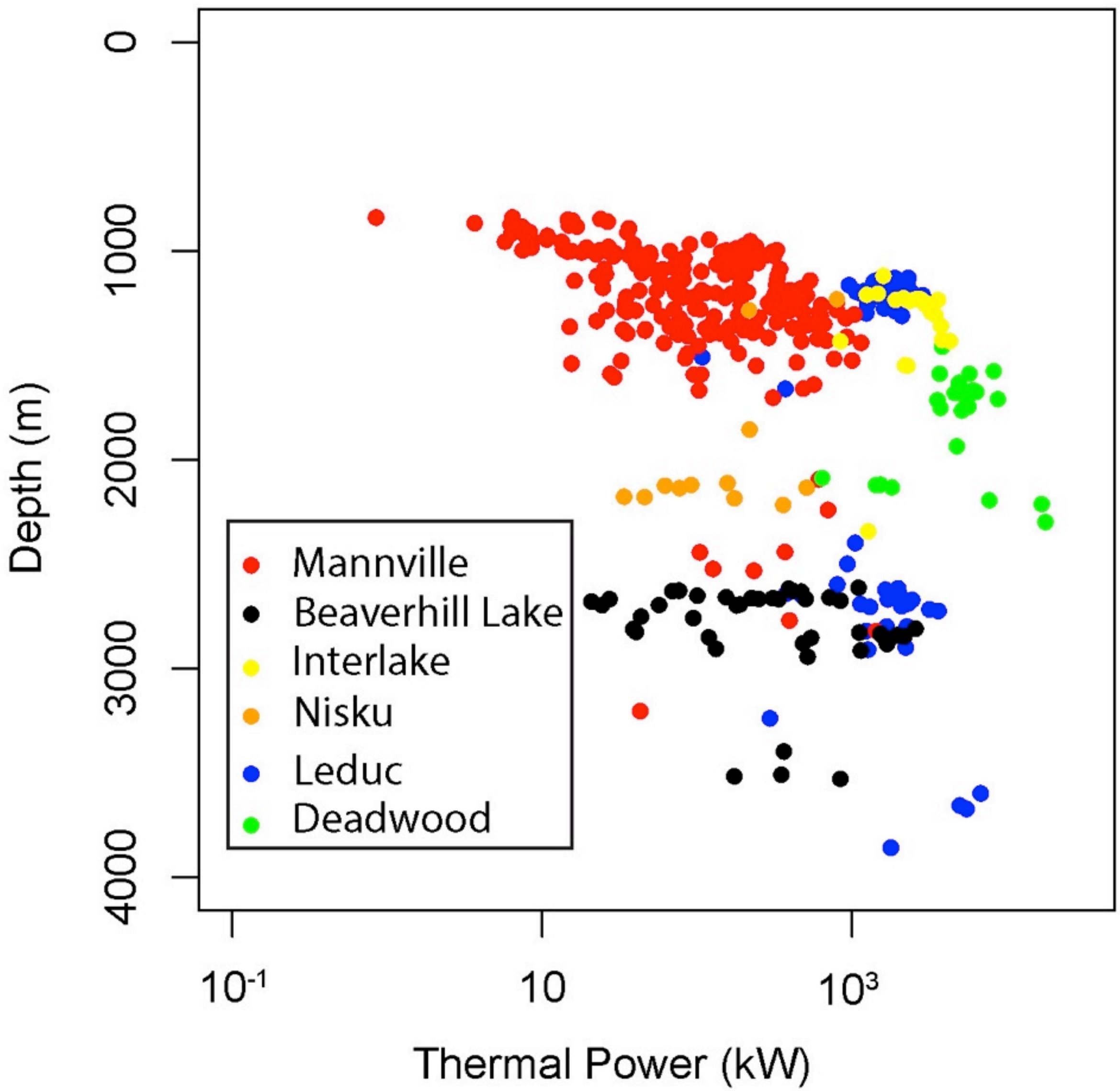


Injection tracks production of coproduced water in oil reservoirs



Water production -
Water injection -

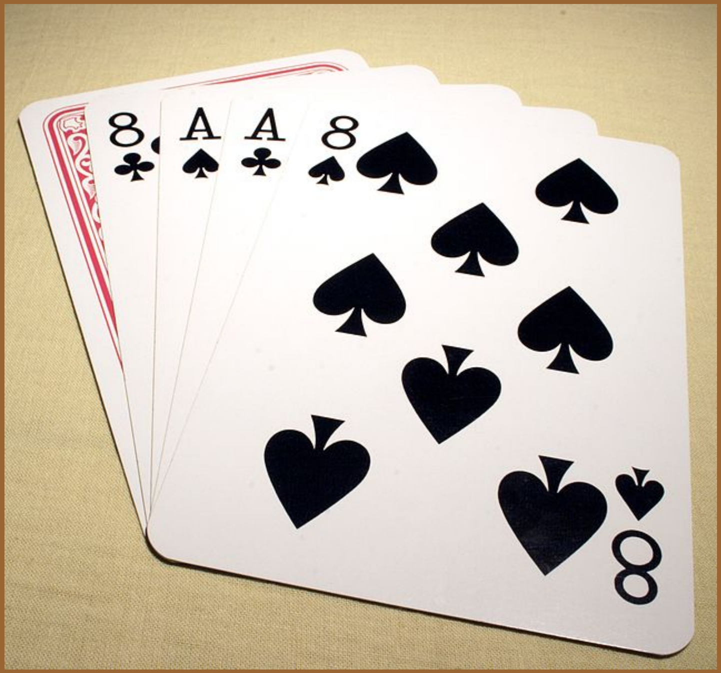
Large injection capacity outside of depleted oil reservoirs



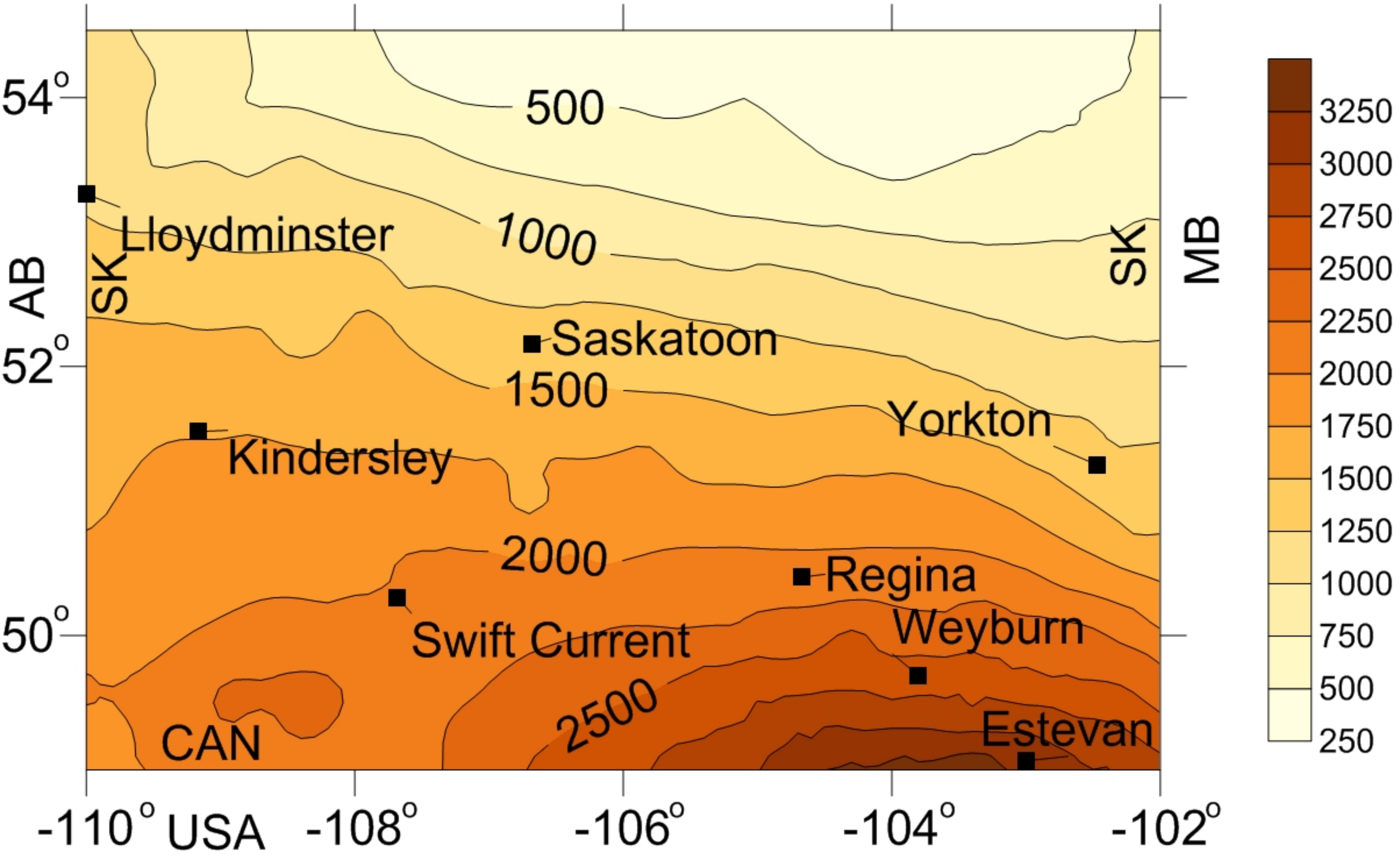
Depth (m)
0
1000
2000
3000
4000
Thermal Power (kW)
10-1
10
103
Mannville
Beaverhill Lake
Interlake
Nisku
Leduc
Deadwood

The potash industry injects 30 million m^3 of brine into the Deadwood and Interlake formations each year.

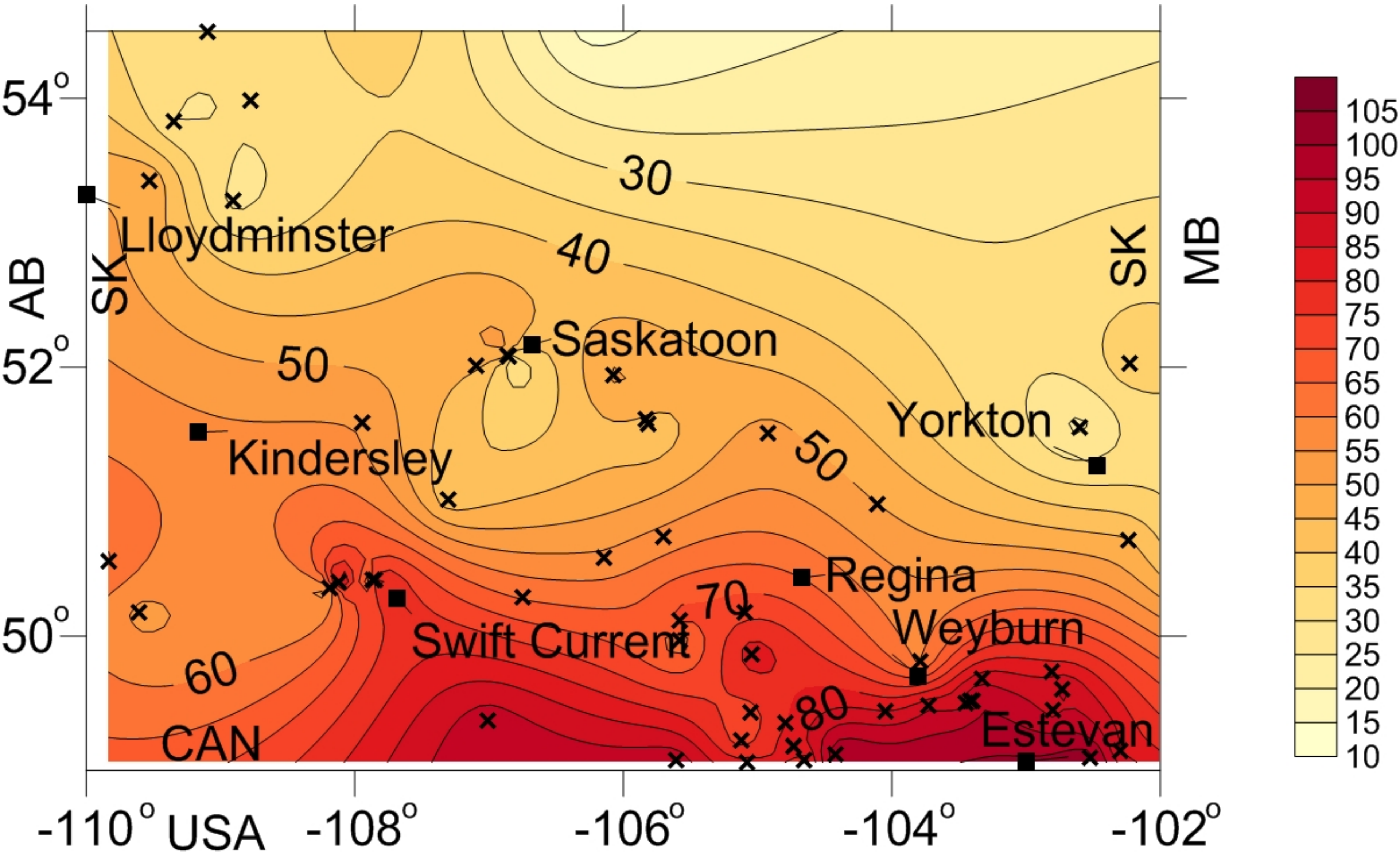
THE DEADWOOD



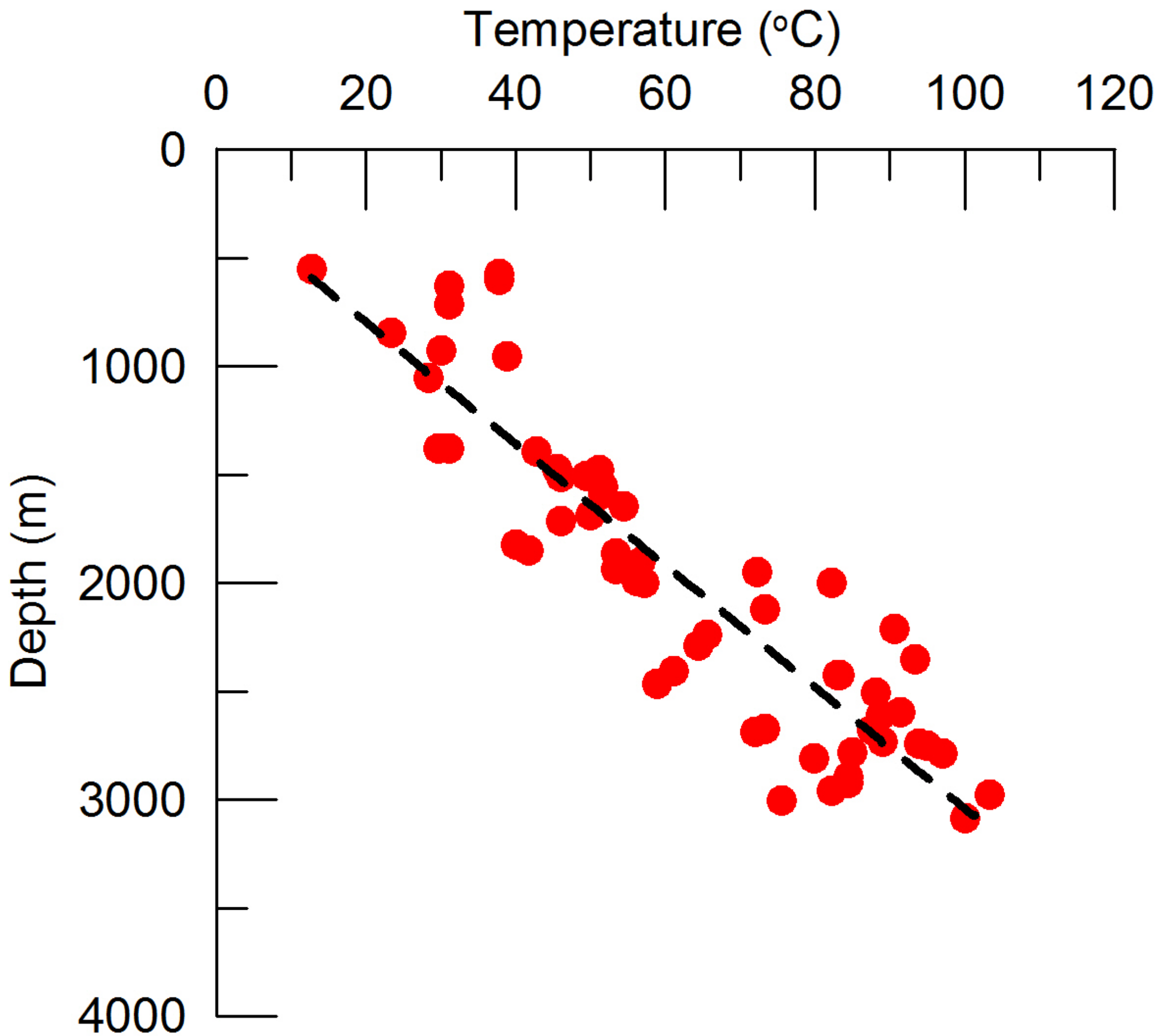
Depth to Deadwood (m)



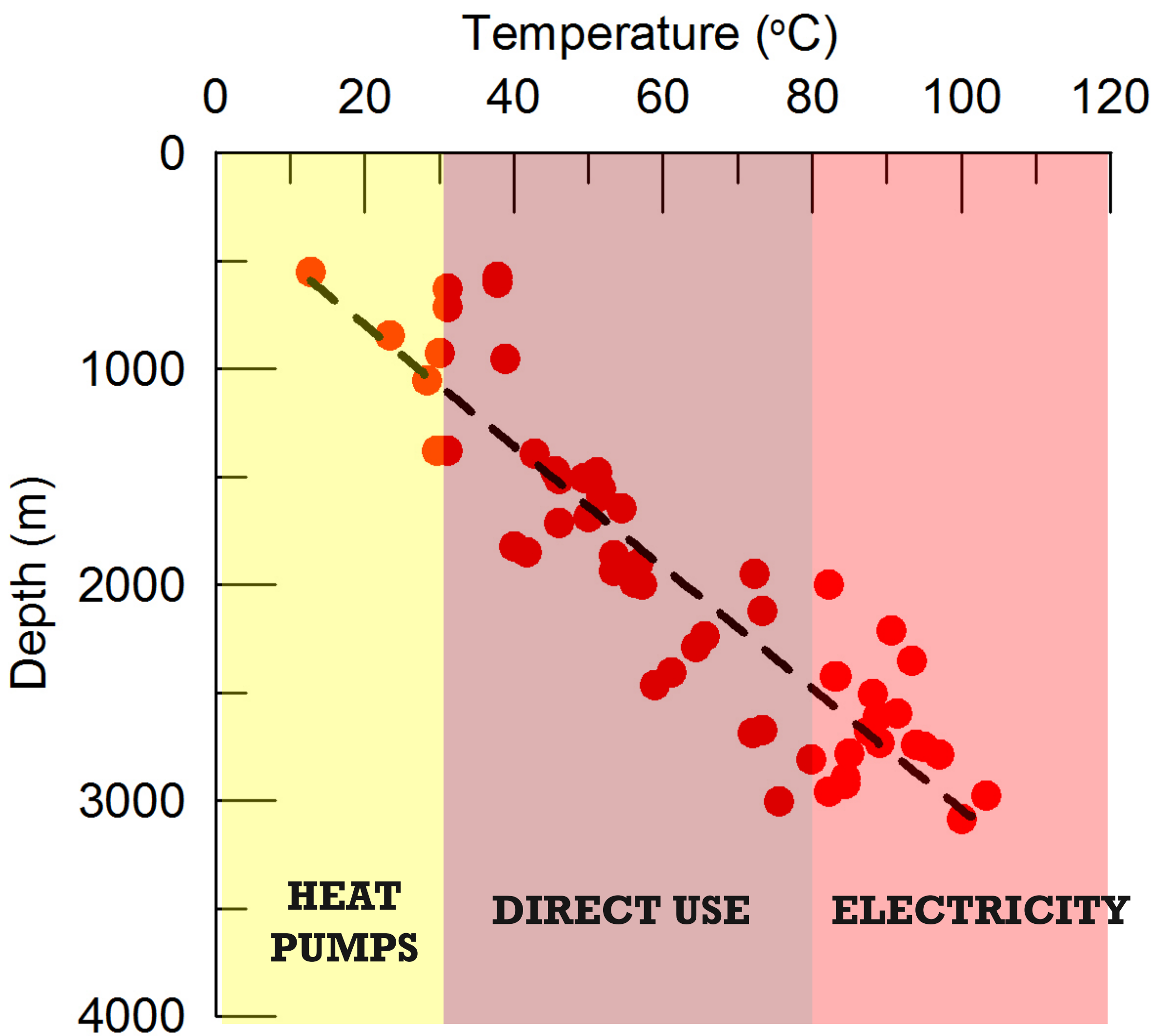
Deadwood Temperatures (°C)

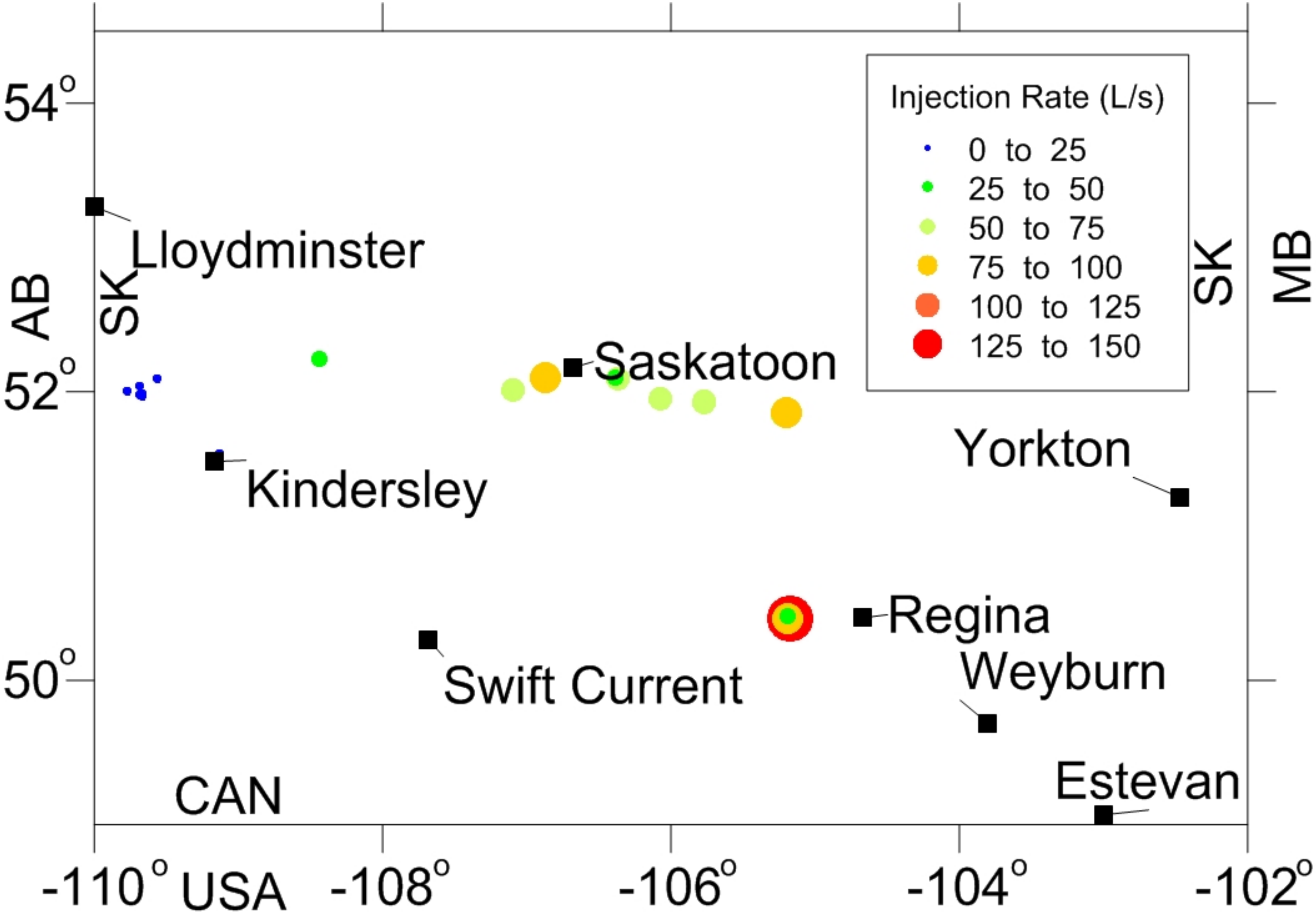


Deadwood Temperatures (°C)



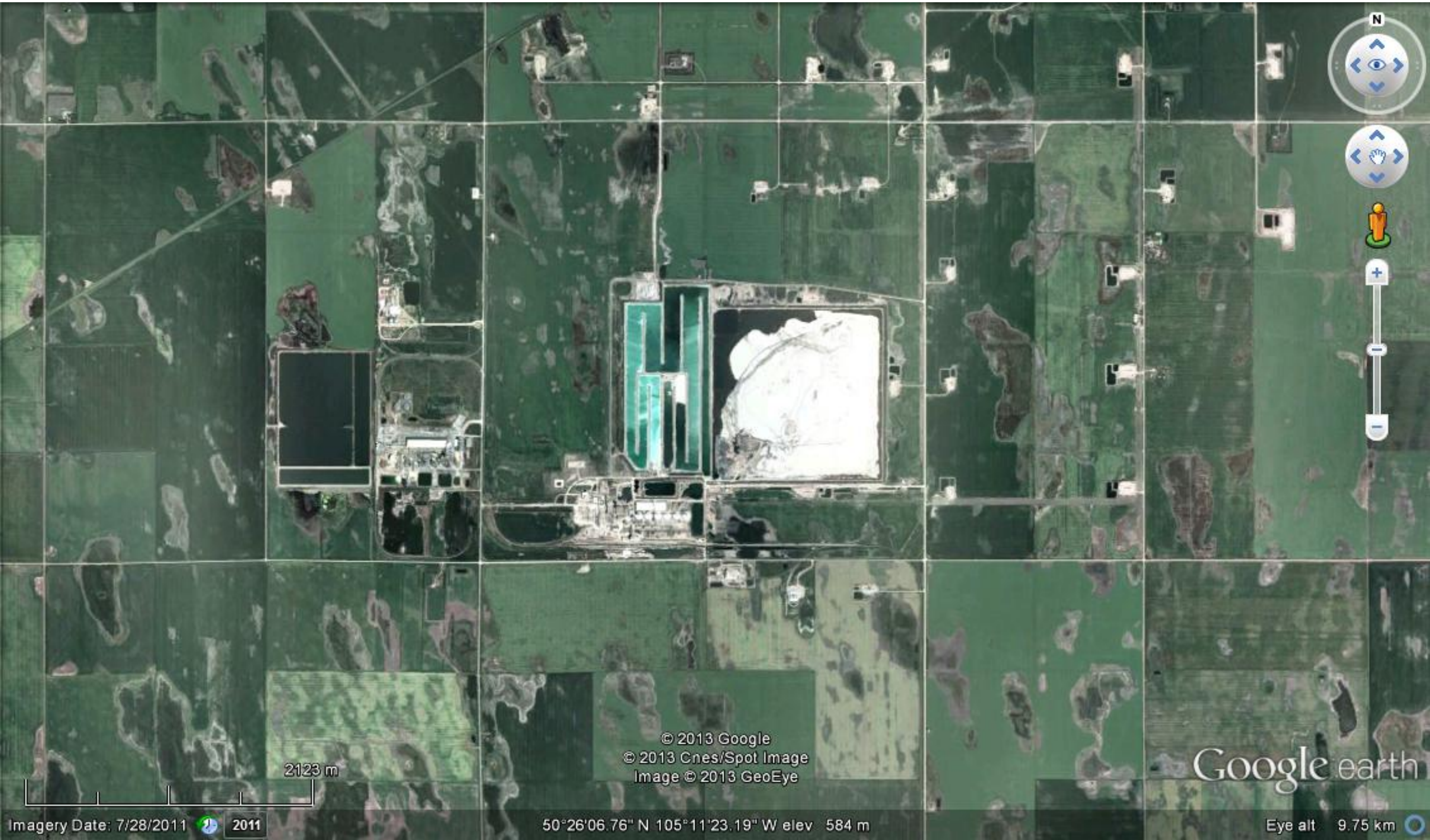
Deadwood Temperatures (°C)





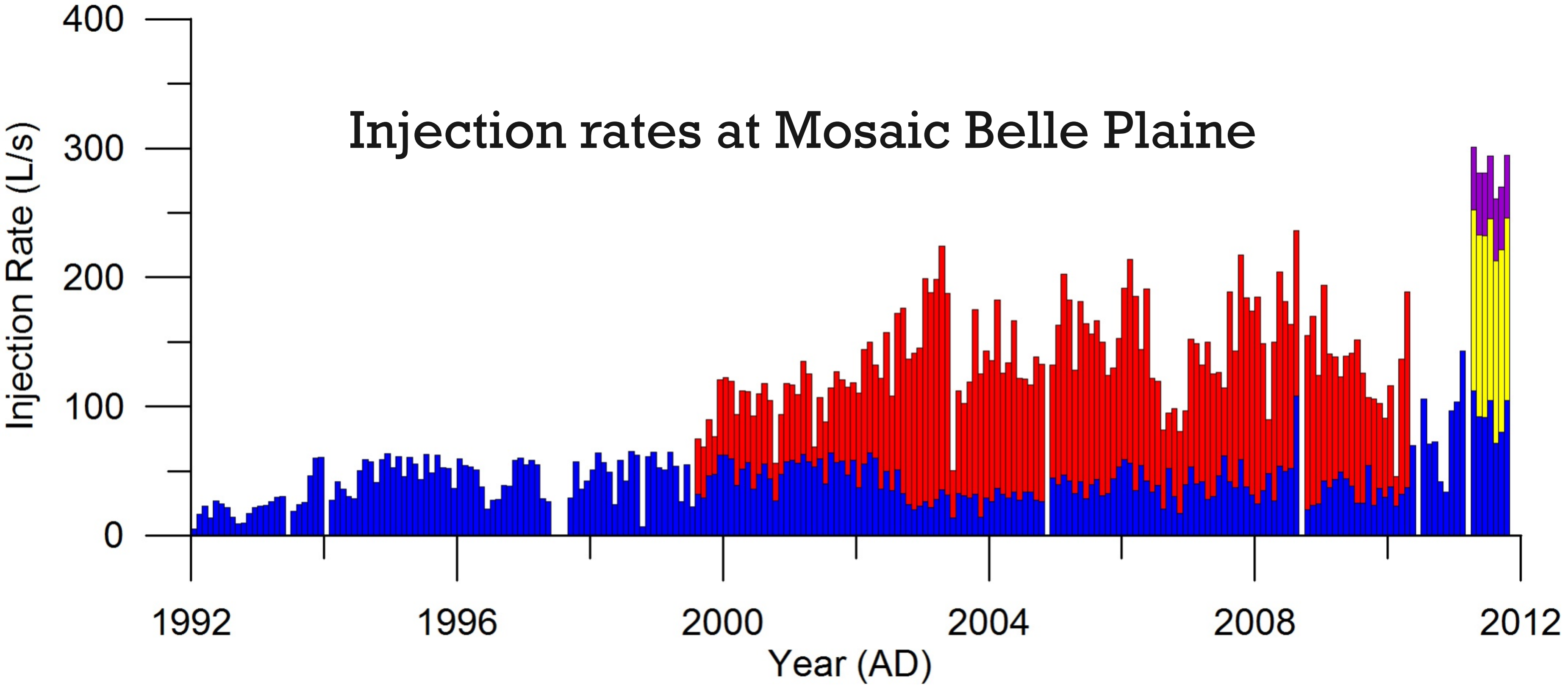
Injection Rate (L/s)
0 to 25
25 to 50
50 to 75
75 to 100
100 to 125
125 to 150
54°
52°
50°
-110°
-108°
-106°
-104°
-102°
AB
SK
SK
MB
CAN
USA
Lloydminster
Saskatoon
Kindersley
Yorkton
Regina
Weyburn
Swift Current
Estevan

Mosaic Belle Plaine



Very high injection rates possible in the Deadwood

100 L/s converts to ~ 15 MW_{th}



Regina Geothermal Project

Laurence Vigrass [1], Alan Jessop [2], and Brian Brunskill [3]

Vigrass, L., Jessop, A., and Brunskill, B. (2007): Regina Geothermal Project; *in* Summary of Investigations 2007, Volume 1, Saskatchewan Geological Survey, Sask. Industry Resources, Misc. Rep. 2007-4.1, CD-ROM, Paper A-2, 21p.

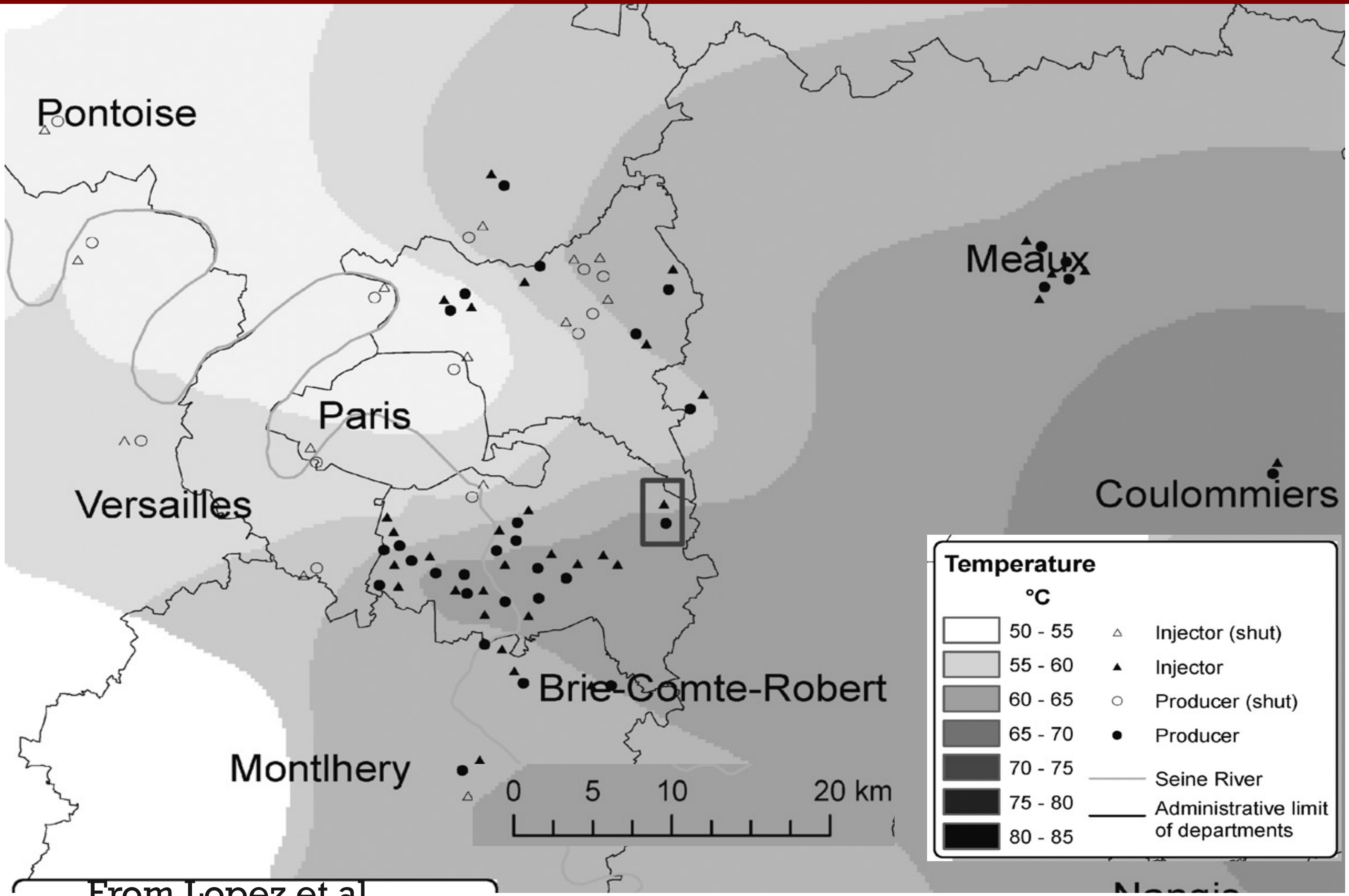
Abstract

In sedimentary basins, the temperature increases downward at an average rate of 30°C per kilometre of depth. Where large volumes of water occur at temperatures above 50°C, immense amounts of energy are available. Sedimentary basin geothermal energy is, utilized in France where installed capacity in 2005 was 308 MW.

In winter 1978, a 2226 m deep geothermal test well, funded by Energy, Mines and Resources Canada (EMR, the predecessor of Natural Resources Canada), was completed on the University of Regina campus. The project was to supply heating for a sports complex and to serve as a demonstration of sedimentary basin geothermal energy. The proposed project involved production of hot water from the geothermal reservoir, passing the hot water through a heat exchanger, and transferring the heat to a fresh-water circuit that would carry the heated fresh water to the point of utilization. The cooled geothermal brine would be injected into the producing reservoir through a disposal well about a kilometre distant. Plans for the sports complex were shelved. This, coupled with decreasing energy prices, resulted in the termination of the project. The knowledge acquired from the test well will be useful in designing geothermal projects proposed for the Regina area or elsewhere.

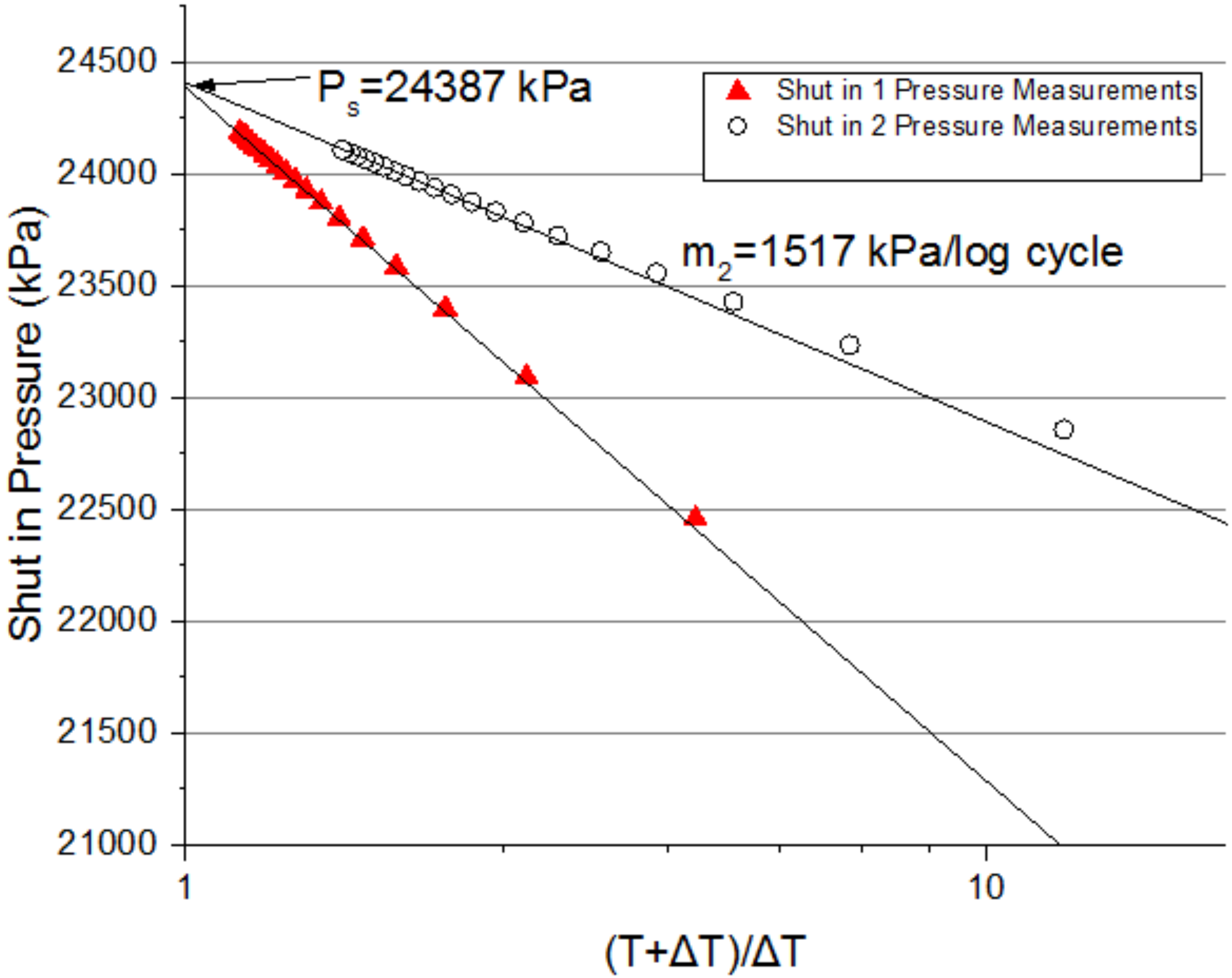
The well was completed in Winnipeg-Deadwood strata with open hole from 2034 to 2226 m. The open section has 111 m of net effective sandstone reservoir with an average porosity of 13.2%; two six-hour pump tests indicate average permeability of 350 mD. With long-term pumping at 100 m^3/h, it is considered that drawdown will stabilize 150 m below ground surface. Bottom-hole temperature is 61°C and, when pumped at 100 m^3/h (440 usgpm), it is expected that the surface temperature of produced water will be 59°C. The fluid is sodium-chloride-sulphate brine with approximately 108 500 g/m^3 of total dissolved solids. Estimated content of CO_2 and H_2S are 56 g/m^3 and 26 g/m^3 respectively. On a short-term (103 hours) test, corrosion rates with ferrous metals were low and fall into an

Similar systems have been operating in the Dogger aquifer, France for decades

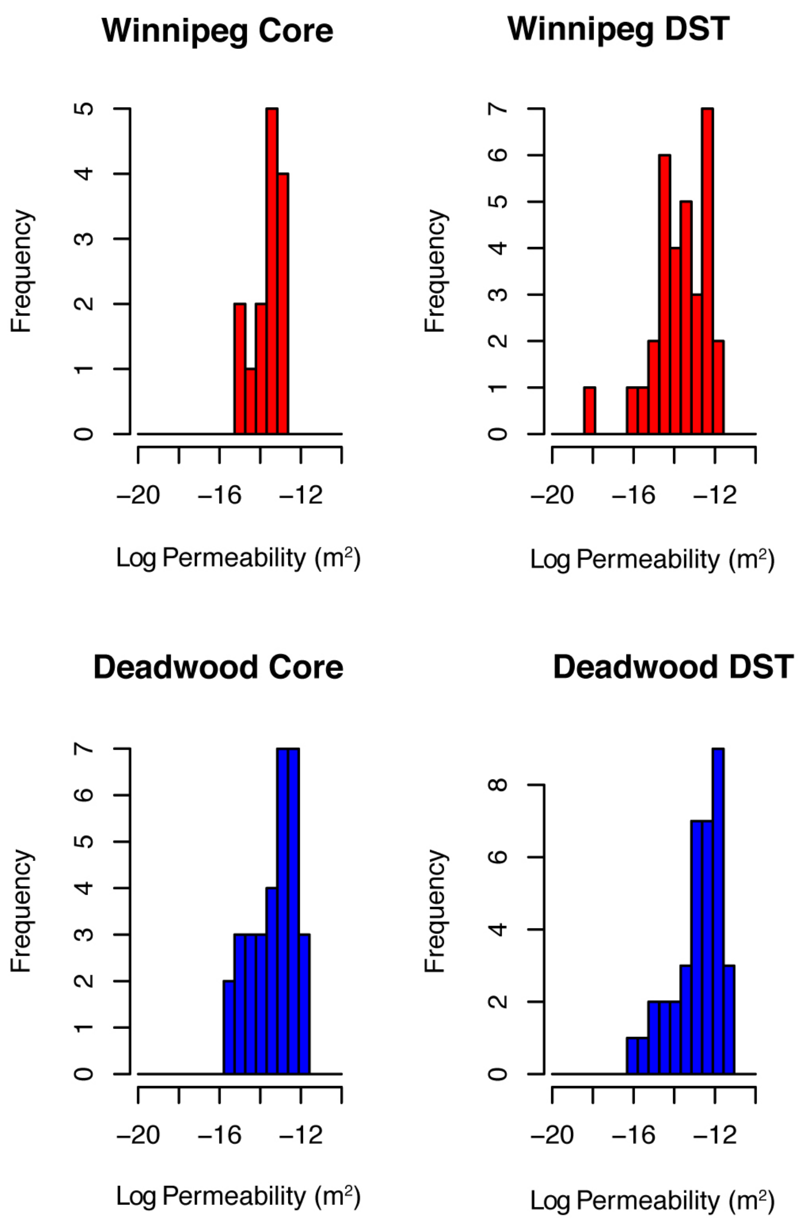


From Lopez et al.,

So what’s the hold up here?

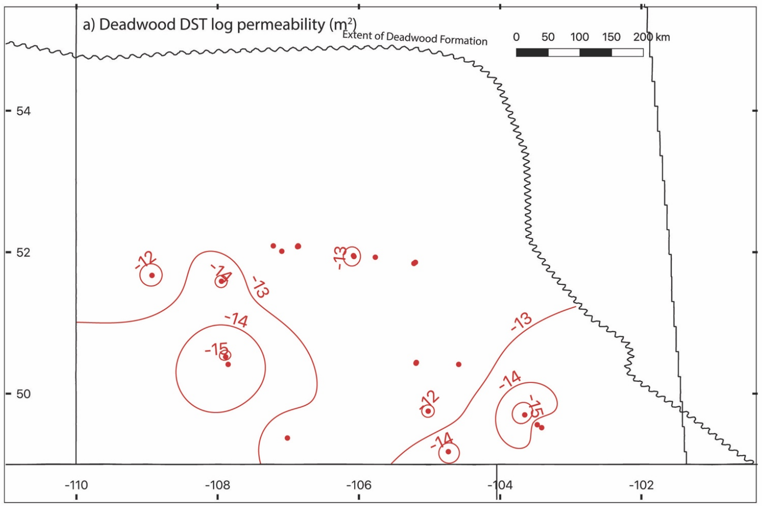


Shut in Pressure (kPa)
24500
24000
23500
23000
22500
22000
21500
21000
1
10
(T+ΔT)/ΔT
P_s=24387 kPa
m_2=1517 kPa/log cycle
Shut in 1 Pressure Measurements
Shut in 2 Pressure Measurements

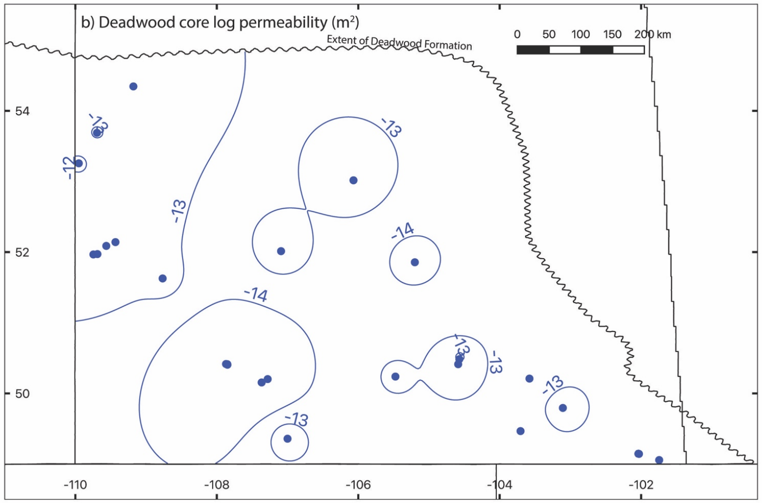


Permeability is a highly variable parameter.

Deep portions of the Deadwood may not support high capacity wells.

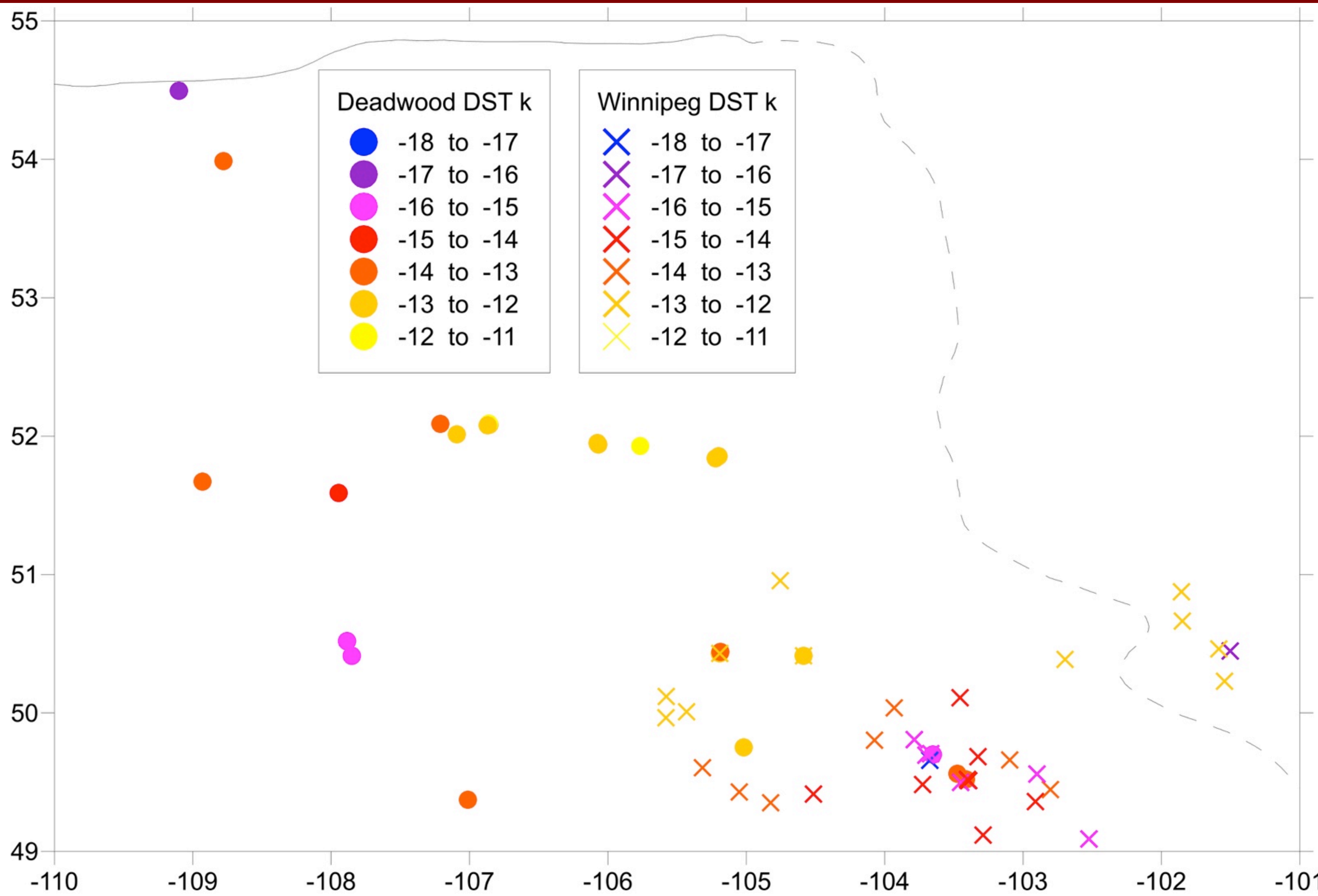


Deadwood Formation permeability from DST



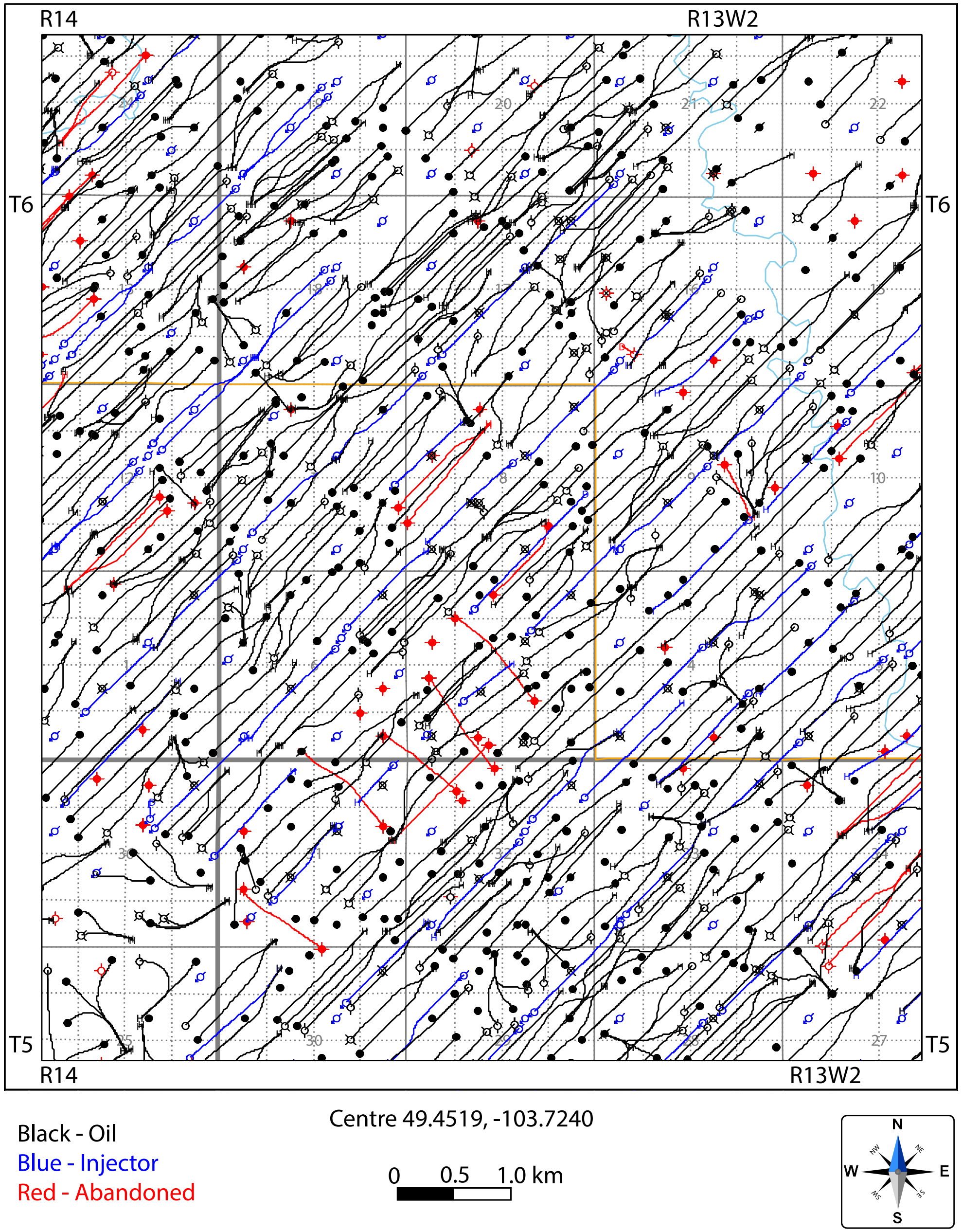
Deadwood Formation permeability from core

Deep portions of the Deadwood may not support high capacity wells.



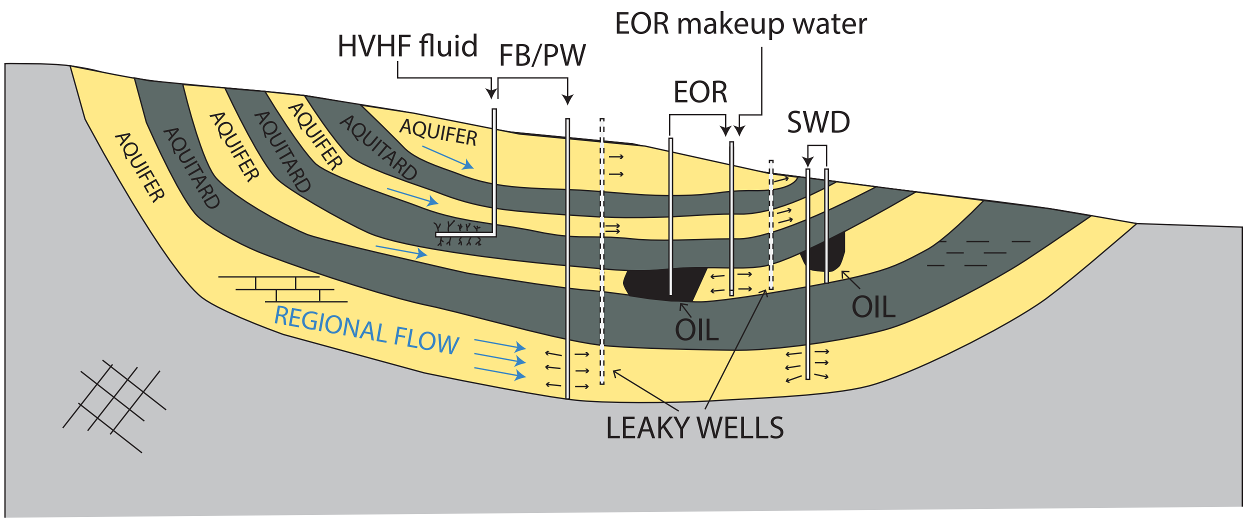
Other considerations…

The subsurface can be a crowded place…



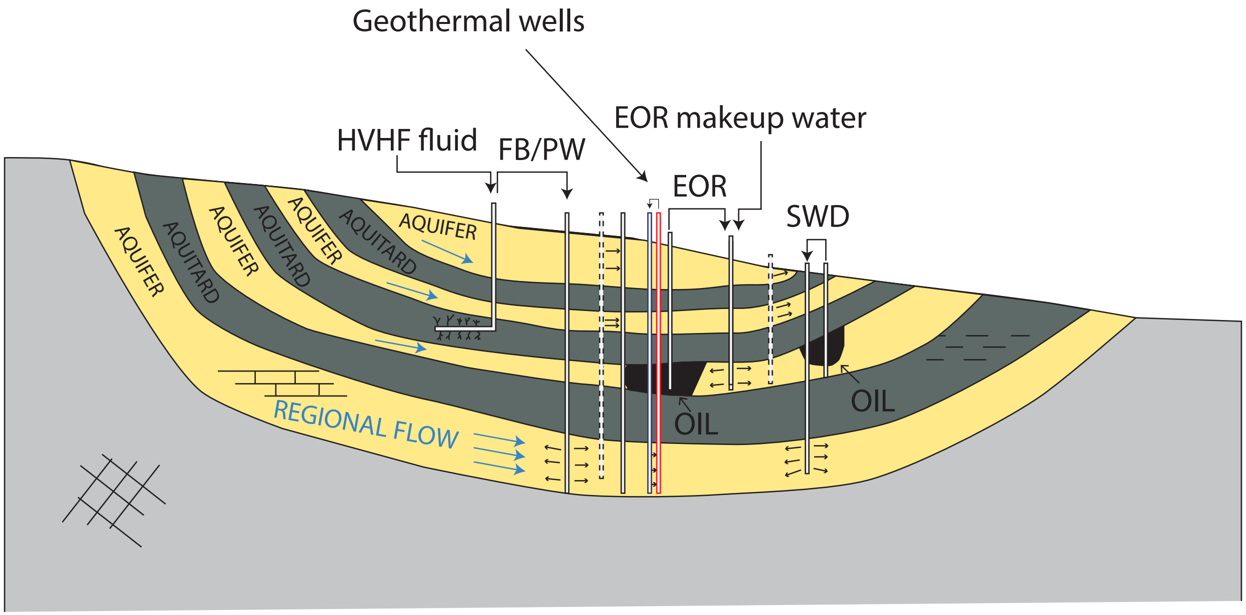
Oil and injection wells, SE Saskatchewan

The Race for Porosity



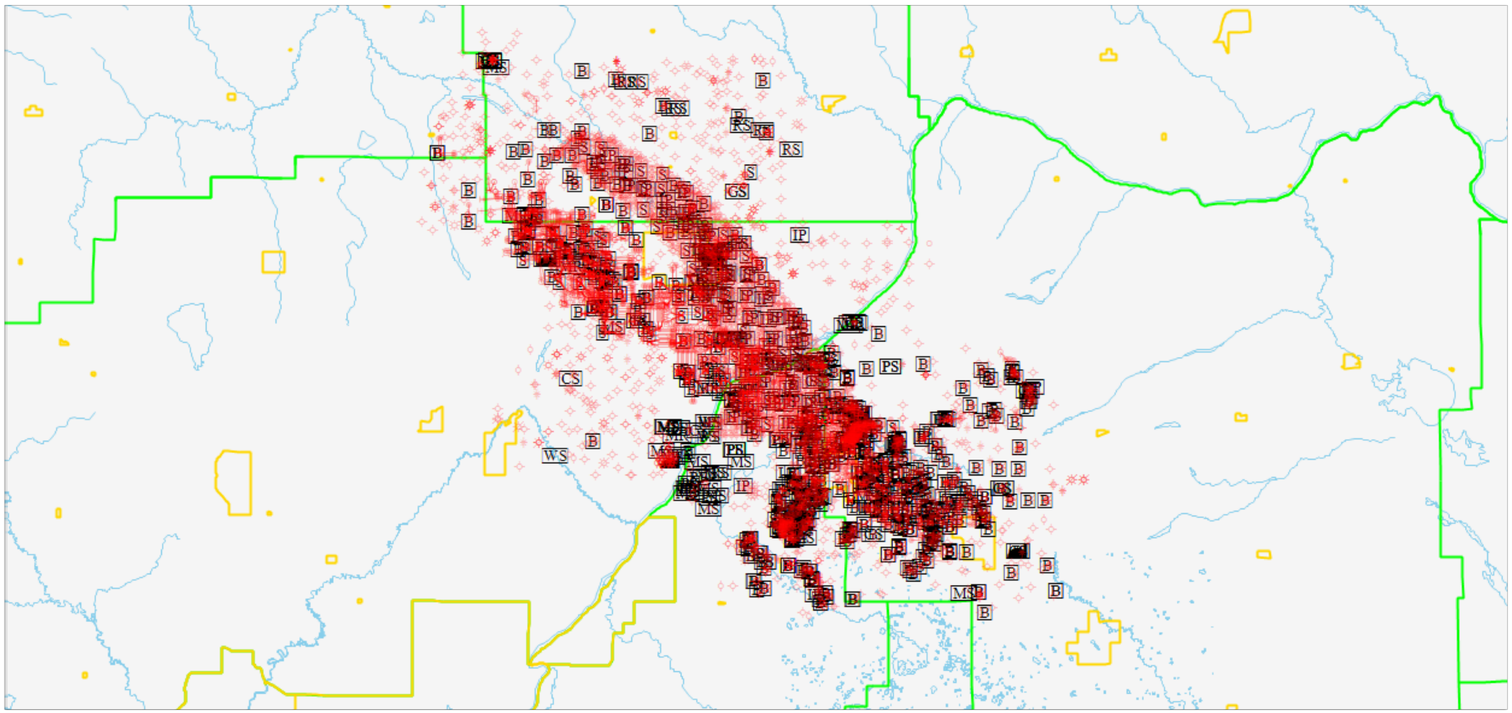
From McIntosh & Ferguson, In review

The Race for Porosity



From McIntosh & Ferguson, in review

Redwater Field, Alberta

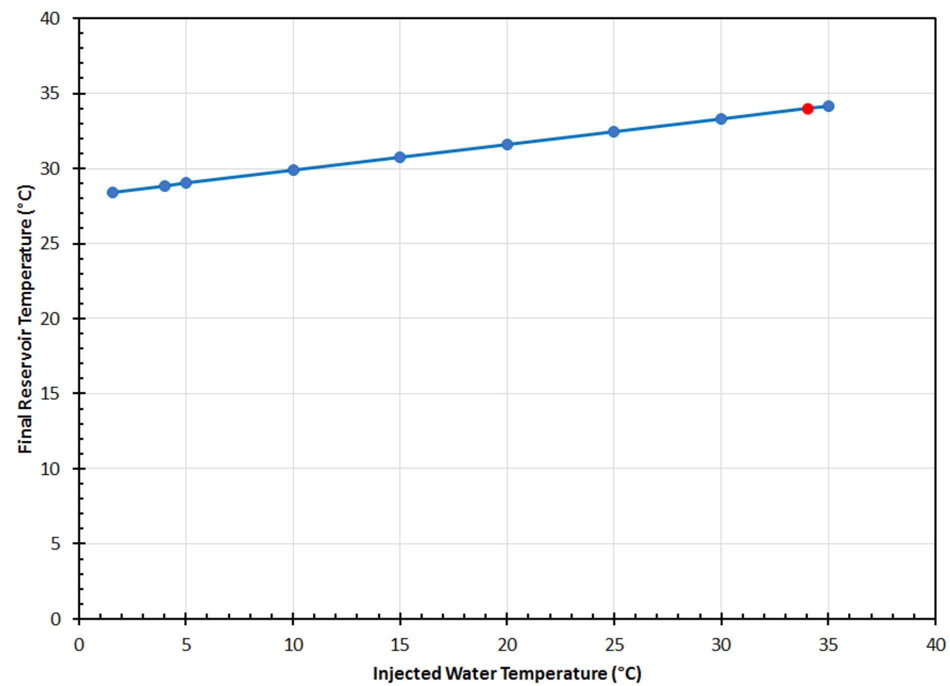


Wells

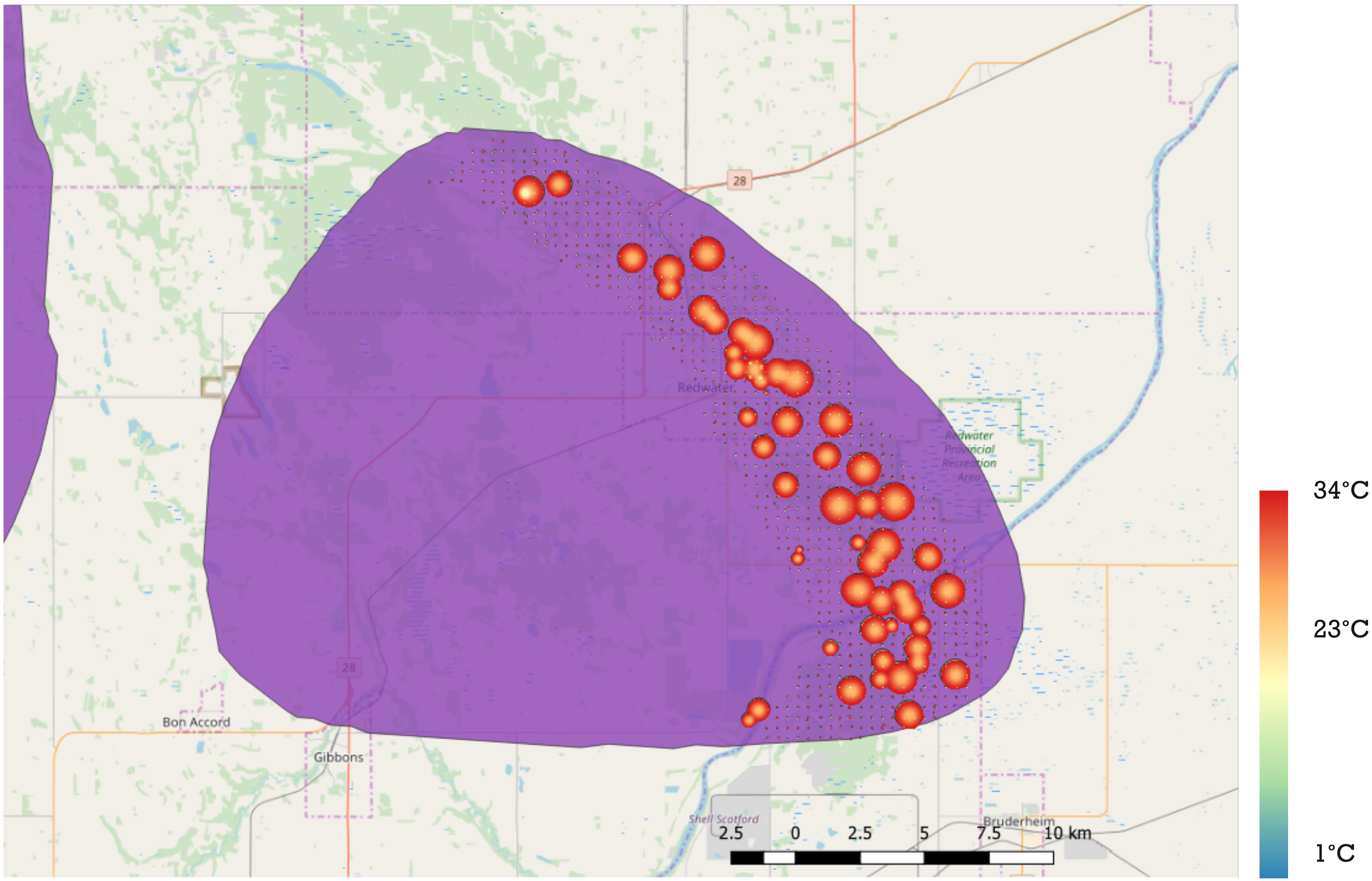
Facilities (Pipelines, Pump Stations, Batteries, etc)

Temperature

- Reservoir temp: ~34 °C
- Injected water is mostly produced water
  - 1.71 km^3 produced vs 1.77 km^3 injected
- Produced water stored on surface
- Average annual temperature at Redwater: 1.6 °C
- Assume mixing in entire reservoir
  - Final temp: 28.4 °C
  - Greater difference around wells



Estimated Temperature Changes



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Geothermics 36 (2007) 185–222

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Induced seismicity associated with Enhanced Geothermal Systems

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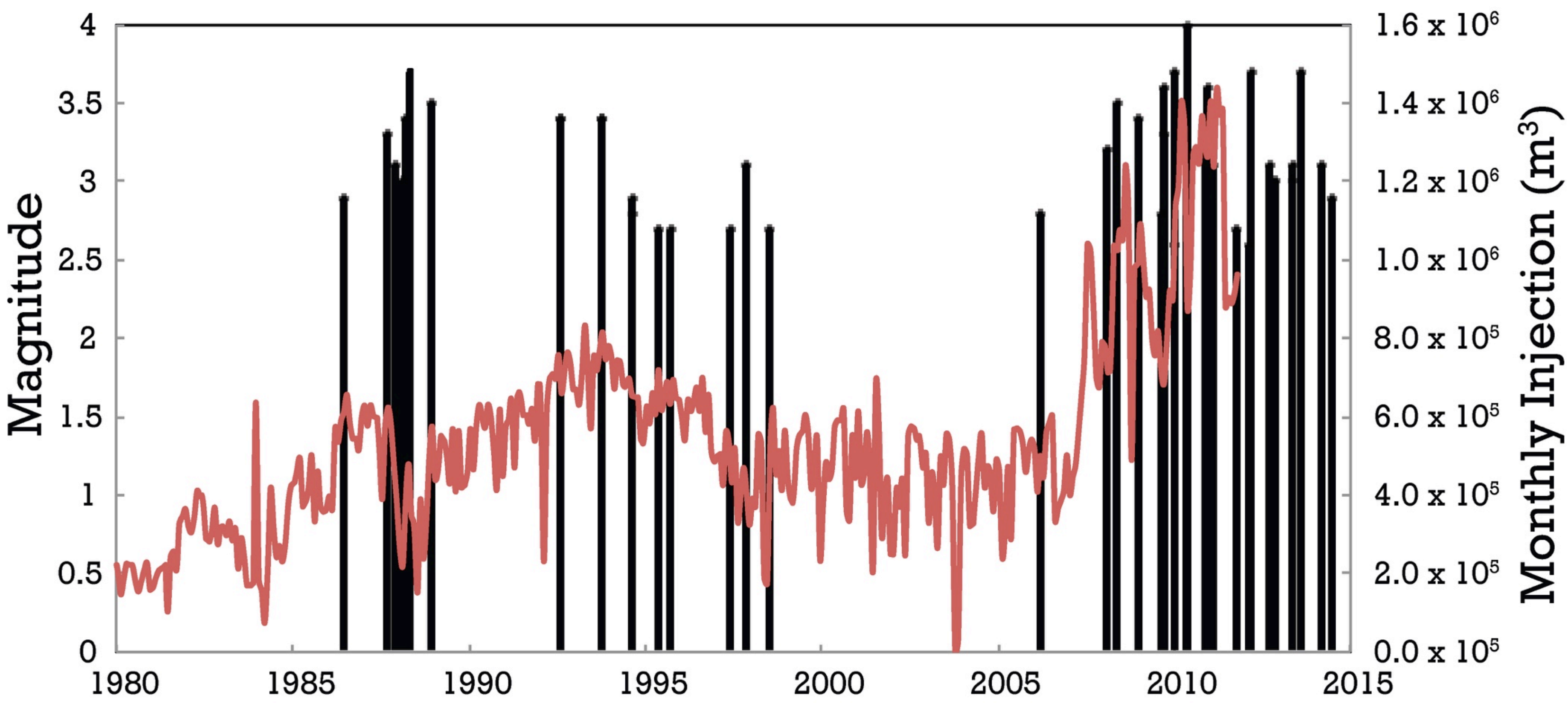
Induced Seismicity at Esterhazy, SK

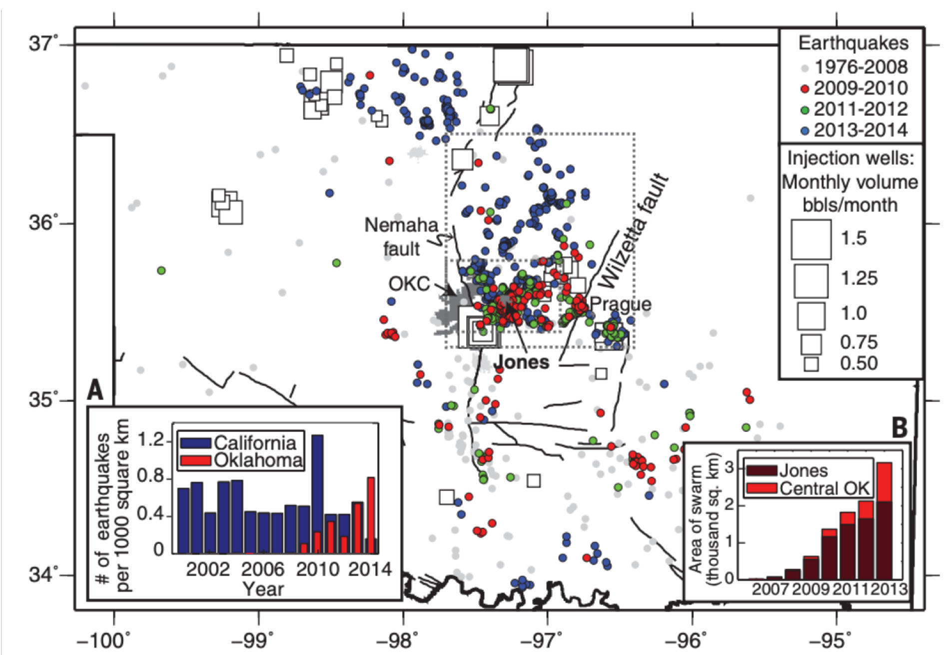


INDUCED EARTHQUAKES

Sharp increase in central Oklahoma seismicity since 2008 induced by massive wastewater injection

K. M. Keranen,[1*] M. Weingarten,[2] G. A. Abers,[3†] B. A. Bekins,[4] S. Ge[2]

Unconventional oil and gas production provides a rapidly growing energy source; however, high-production states in the United States, such as Oklahoma, face sharply rising numbers of earthquakes. Subsurface pressure data required to unequivocally link earthquakes to wastewater injection are rarely accessible. Here we use seismicity and hydrogeological models to show that fluid migration from high-rate disposal wells in Oklahoma is potentially responsible for the largest swarm. Earthquake hypocenters occur within disposal formations and upper basement, between 2- and 5-kilometer depth. The modeled fluid pressure perturbation propagates throughout the same depth range and tracks earthquakes to distances of 35 kilometers, with a triggering threshold of ~0.07 megapascals. Although thousands of disposal wells operate aseismically, four of the highest-rate wells are capable of inducing 20% of 2008 to 2013 central U.S. seismicity.



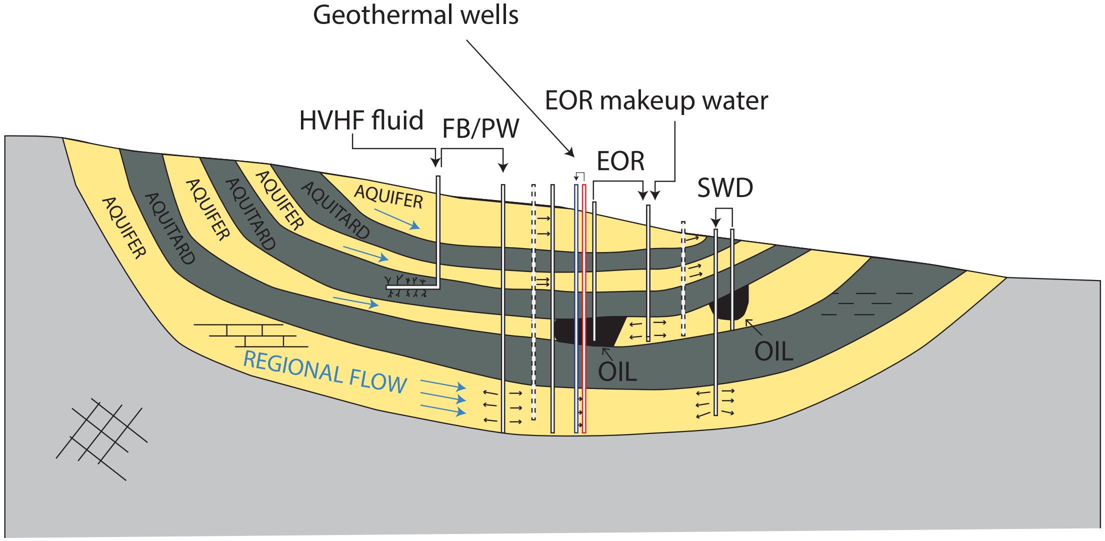
Moving around large volumes of fluid may result in induced seismicity

Pros to developing geothermal energy in sedimentary basins:

- High permeability
- Availability of data

Cons to developing geothermal energy in sedimentary basins:

- Existing infrastructure and changes in temperature
- Low temperatures



From McIntosh & Ferguson, in review