Groundwater Protection - Looking Deeper

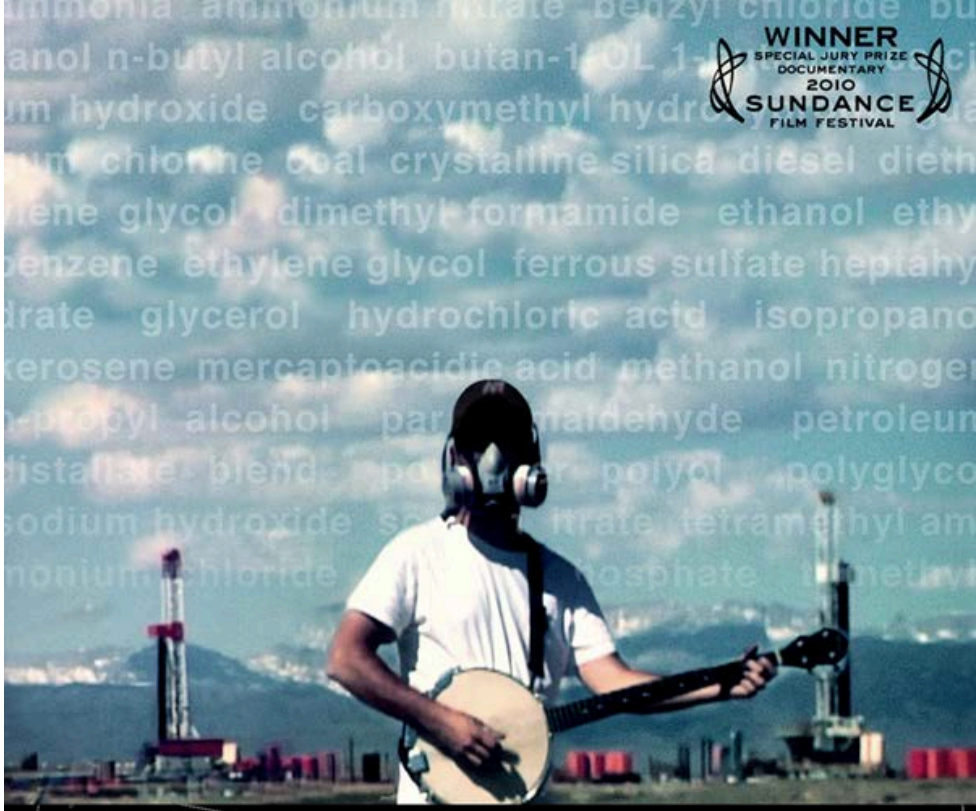
Grant Ferguson, Jennifer C. McIntosh, Matt Lindsay, Stephen E. Grasby, M. Jim Hendry, S. Lee Barbour and Jeffrey McDonnell

UNIVERSITY OF SASKATCHEWAN

ARIZONA

CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

Jennifer C. McIntosh
University of Arizona



GASLAND

Can you light your water on fire?

PREMIERES MONDAY, JUNE 21 AT 9PM/8C ON HBO

HBO DOCUMENTARY FILMS PRESENTS AN INTERNATIONAL WOW PRODUCTION "GASLAND" A FILM BY JOSH FOX EDITED BY MATTHEW SANCHEZ
PRODUCED BY TRISH ADLESIC, JOSH FOX AND MOLLY GANDOUR WRITTEN AND DIRECTED BY JOSH FOX

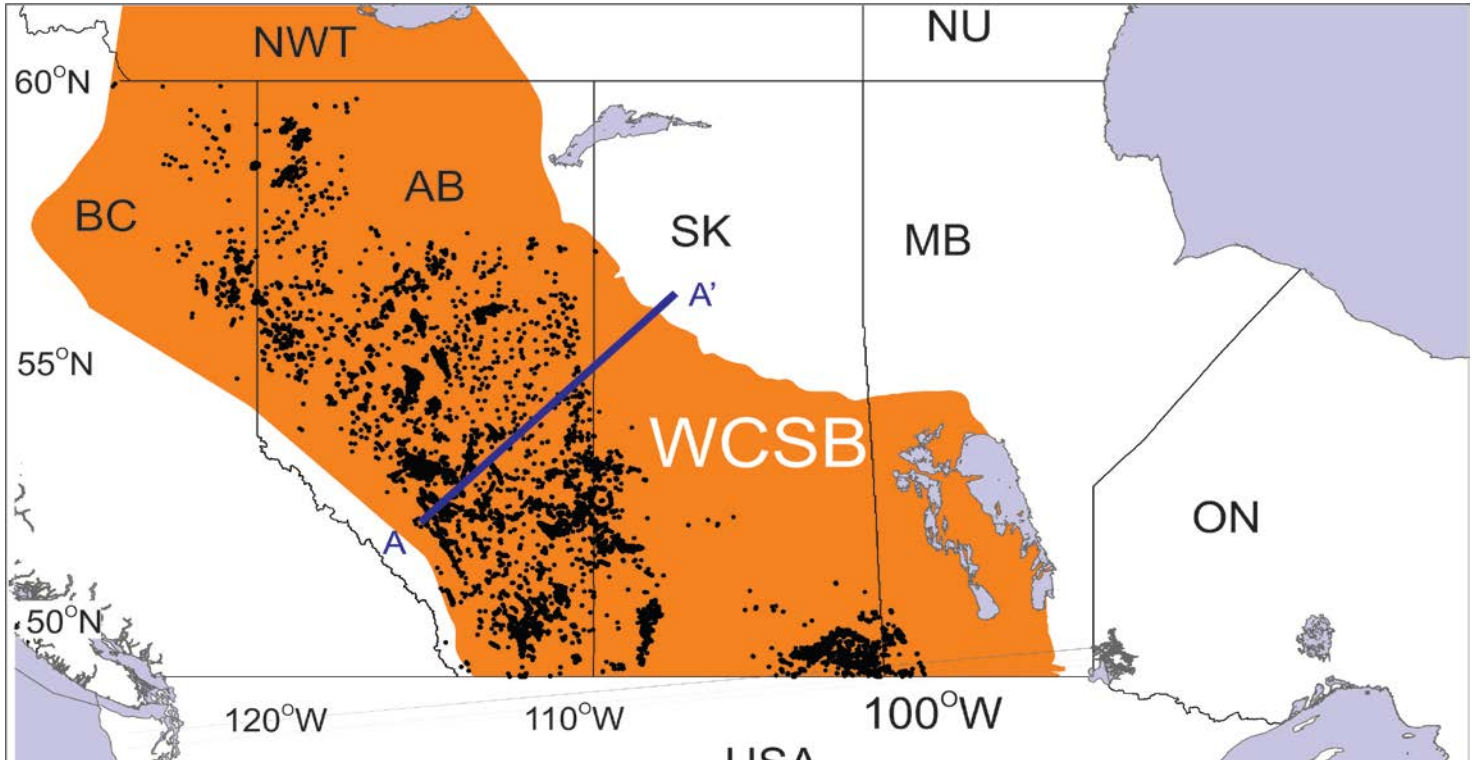

NON AU GAZ DE SCHISTE
COLLECTIF
VALVIGNERES (07)

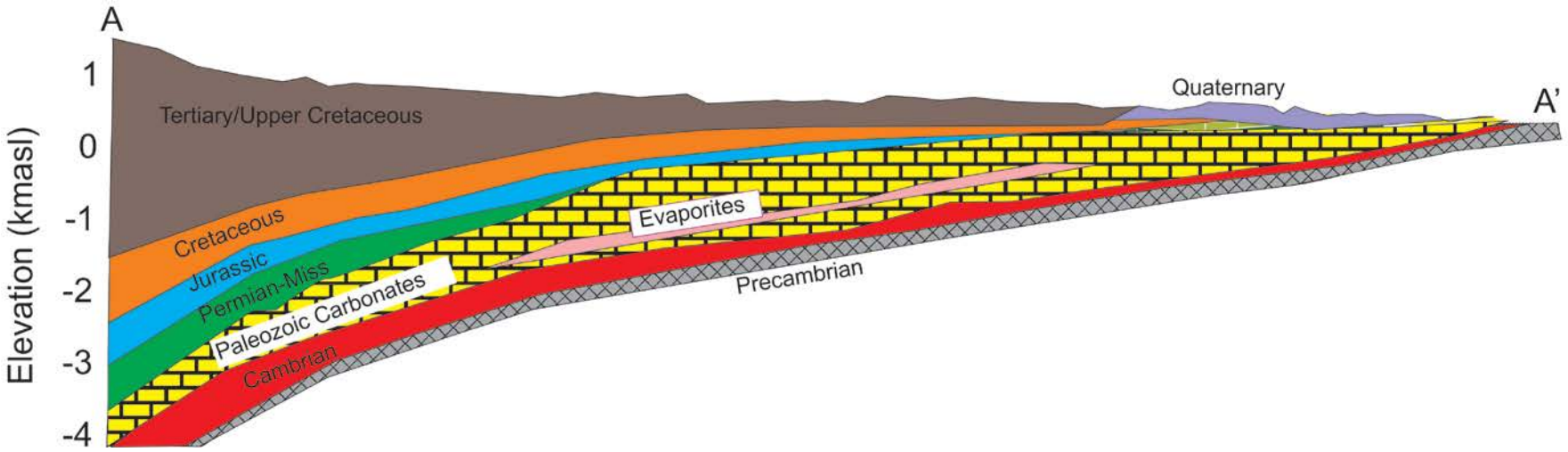

kNOw
SHALE
GAS

Meanwhile in Saskatchewan…

Photo from http://members.kos.net/sdgagnon/vaa.html

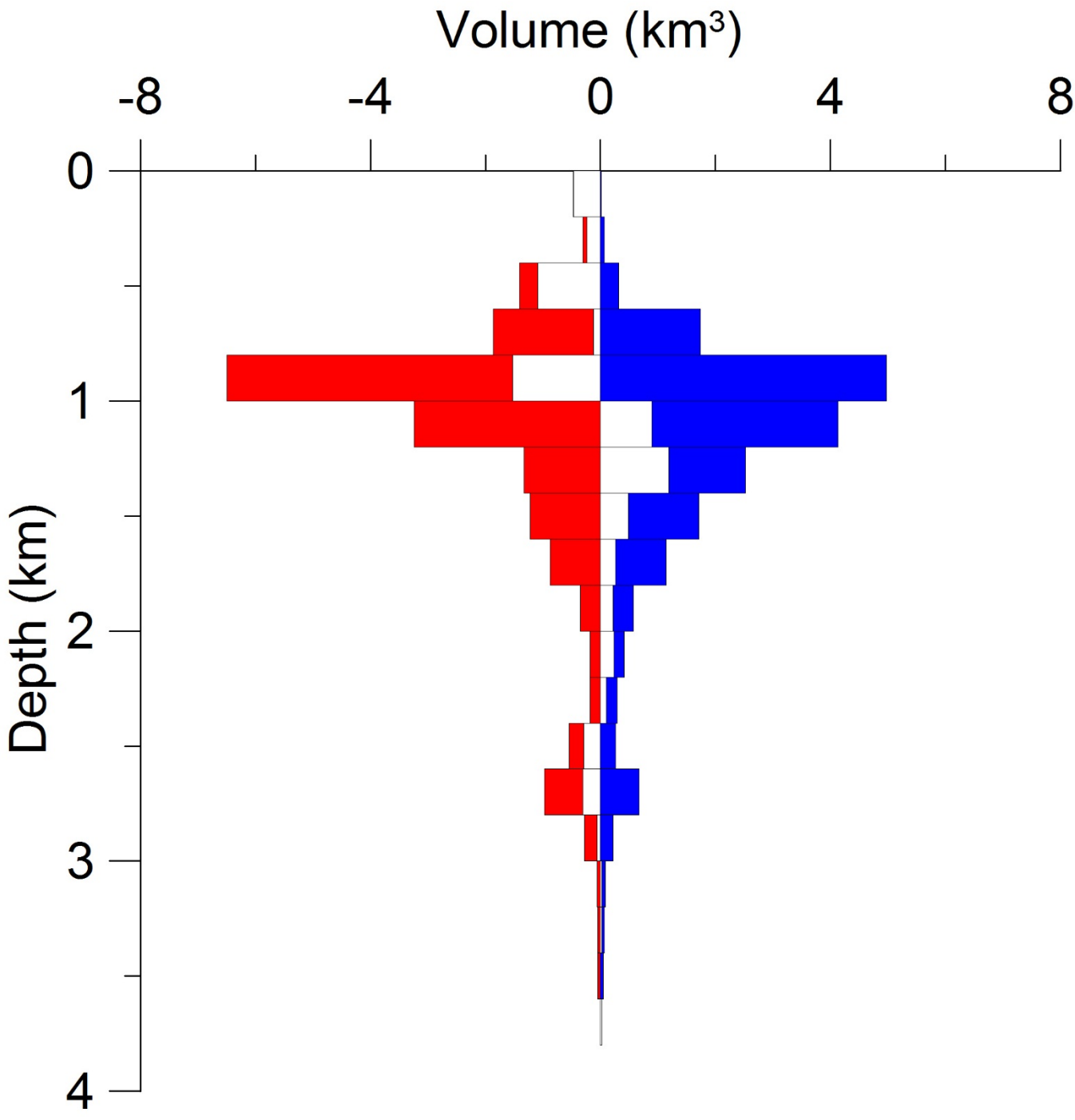
The Western Canada Sedimentary Basin



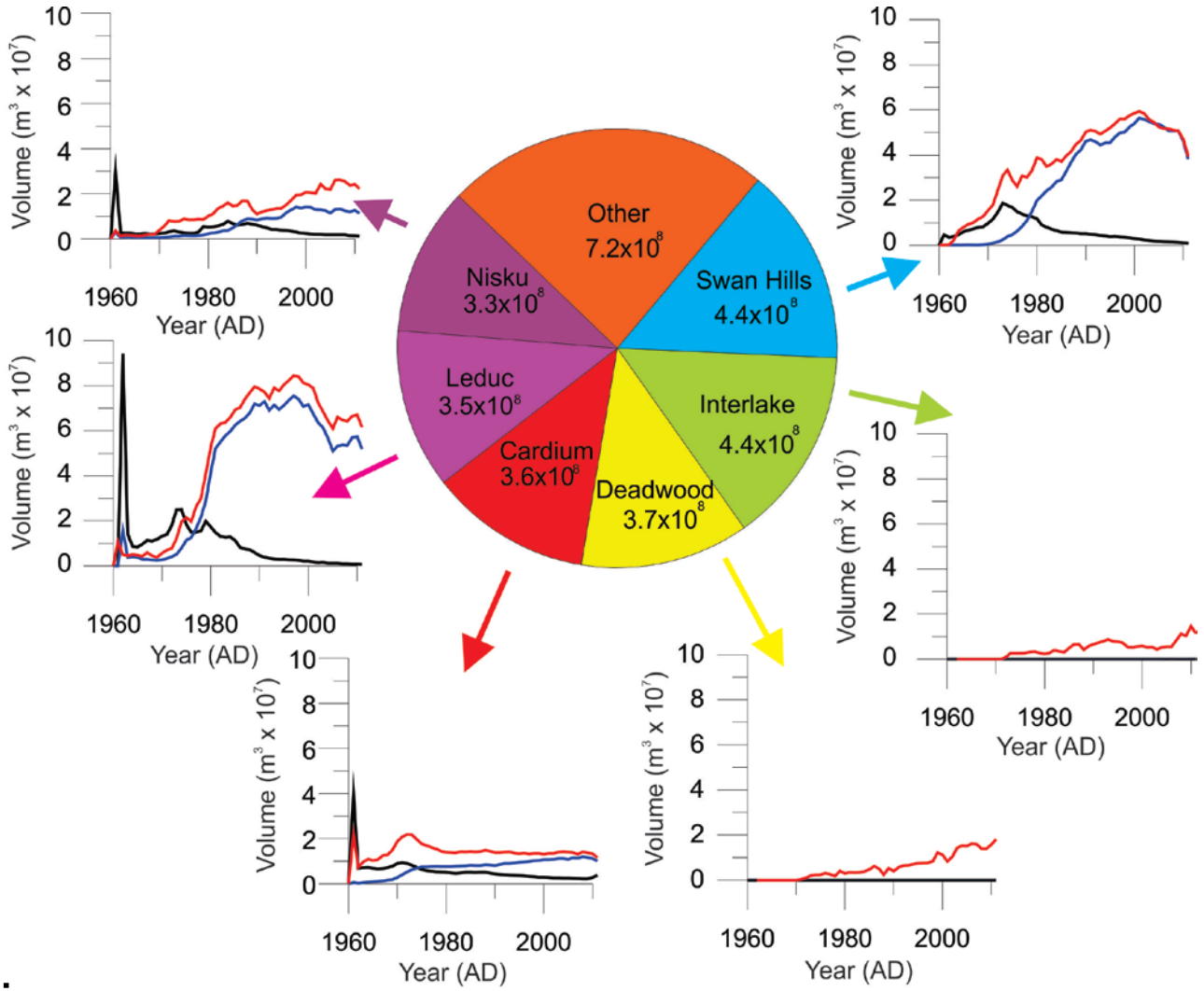


Total injection of 23 km^3

Injection mainly mirrors production



Injection tracks production of coproduced water in oil reservoirs



Oil production -

Water production -

Water injection -

Large injection capacity outside of depleted oil reservoirs

What about the Bakken?

Water use for HVHF in Bakken:

5.8×10^3 - 35×10^3 m^3/well

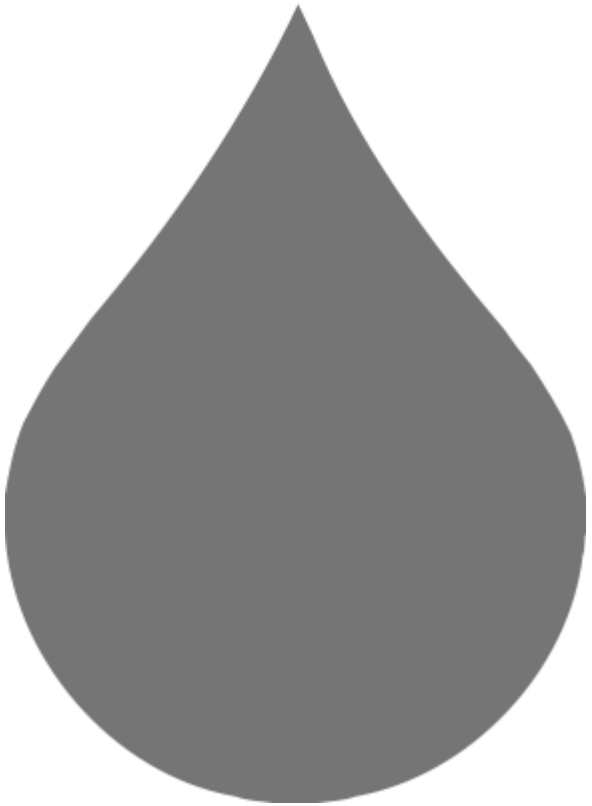
Water use for EOR in same region:

43×10^3 – $1{,}009 \times 10^3$ m^3/well

Injection exceeds deep recharge

recharge through Cretaceous shales during last 10,000 yrs

20 to 50 mm



“recharge” from net injection during last 100 yrs

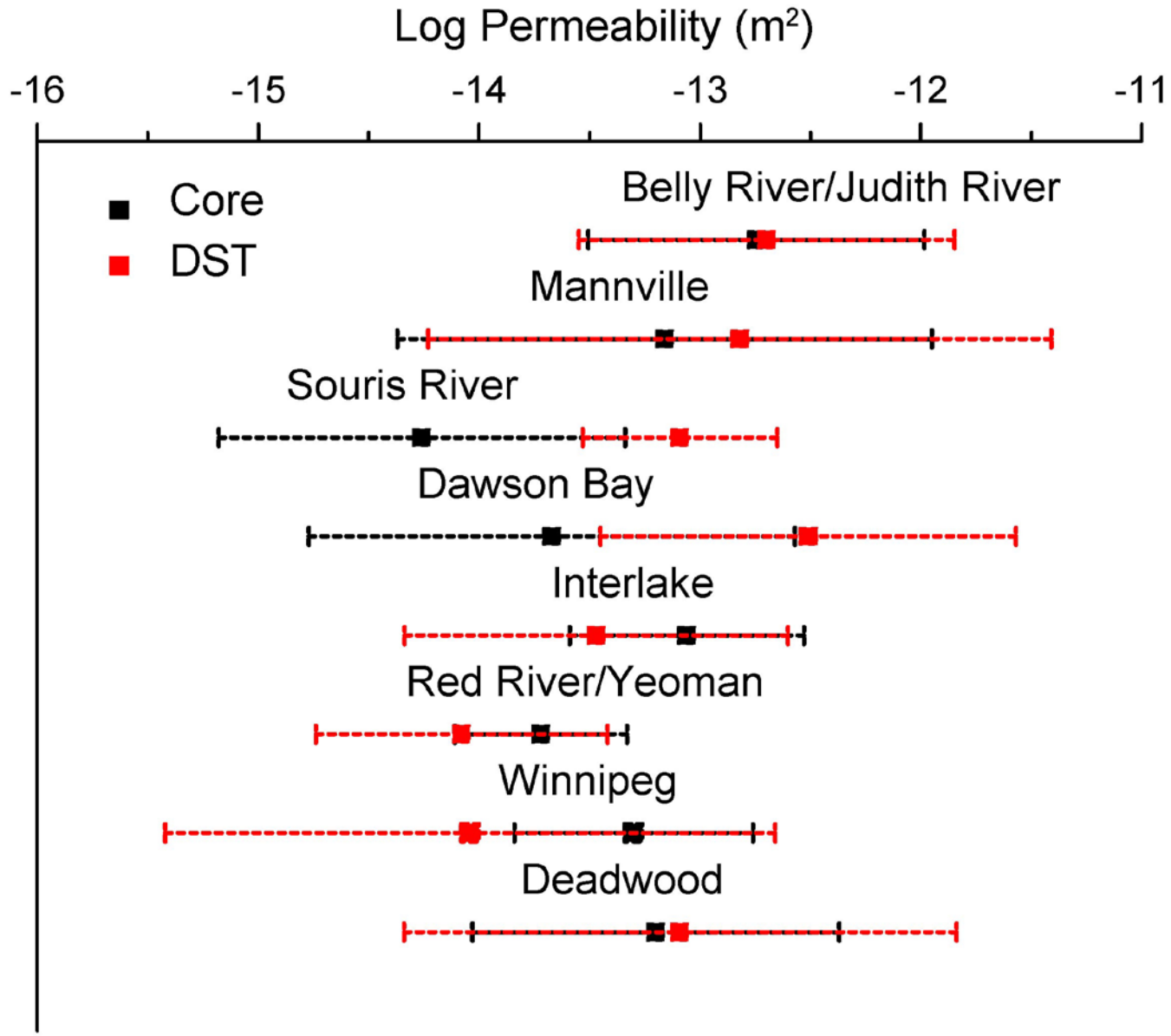
2 mm

Perceived Data Scarcity

…due to the lack of deep wells in south-eastern Saskatchewan, the characterization required significant work and expertise. Aquistore utilized preliminary geological and hydrogeological characterization, 2D seismic, 3D seismic, existing core, and historical well logs to evaluate the site prior to drilling.

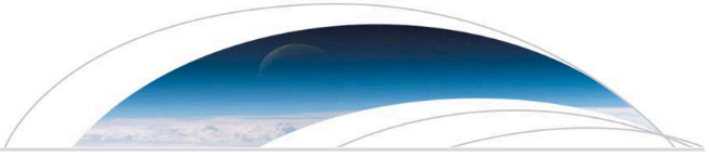
--Global Carbon Capture and Storage Institute Ltd 2015

68,326 DSTs


Log Permeability (m²)
-16
-15
-14
-13
-12
-11
Core
DST
Belly River/Judith River
Mannville
Souris River
Dawson Bay
Interlake
Red River/Yeoman
Winnipeg
Deadwood

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters



RESEARCH LETTER
10.1029/2018GL078409

Key Points:
- There is insufficient topography to drive connate brines from many sedimentary basins
- The ratio of topographic relief to basin depth predicts the presence of stagnant brines
- Basins that do not contain brines either have high topographic gradients, shallow extents, or never contained brines

Supporting Information:
- Supporting Information S1

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The Persistence of Brines in Sedimentary Basins

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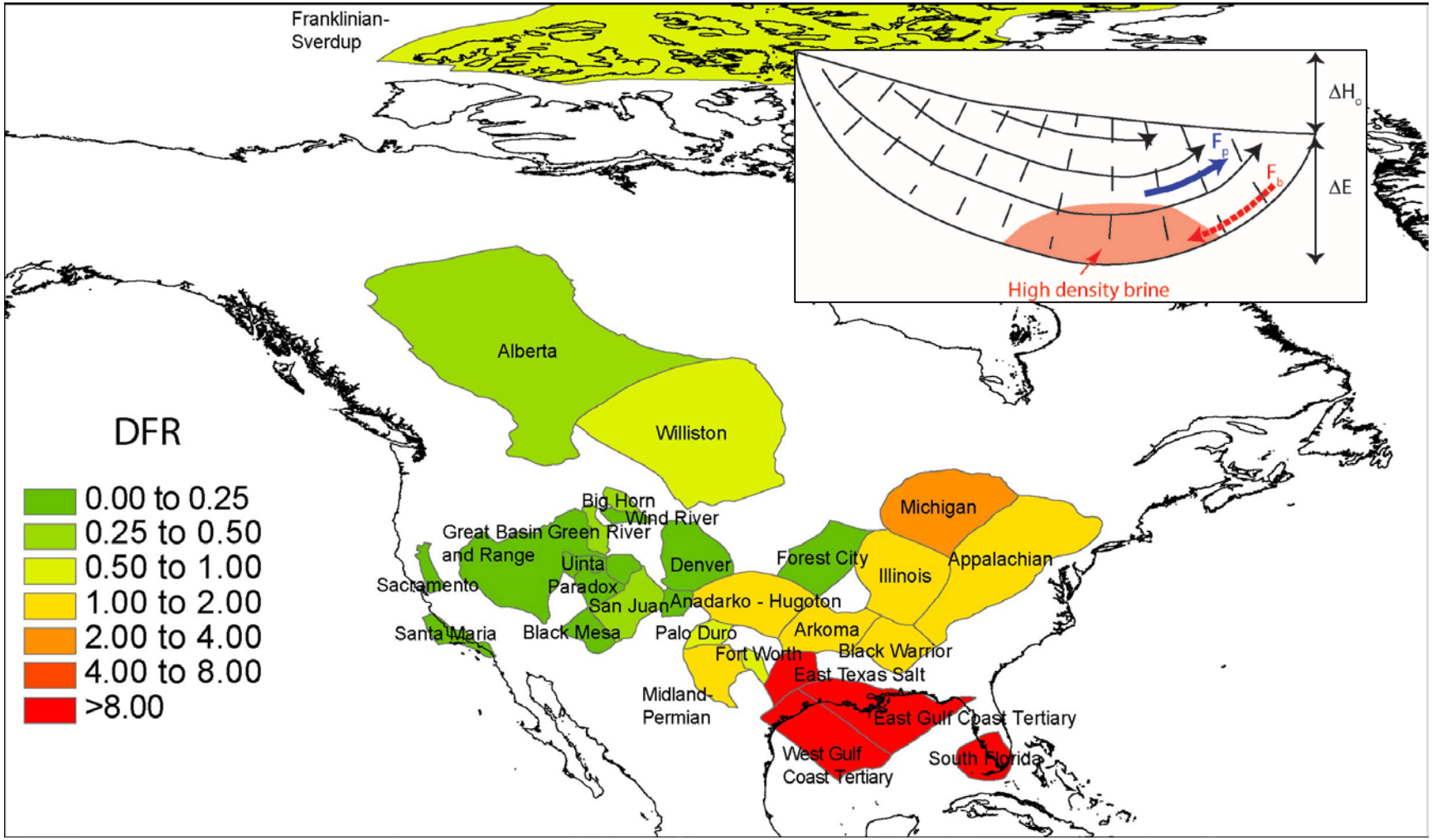
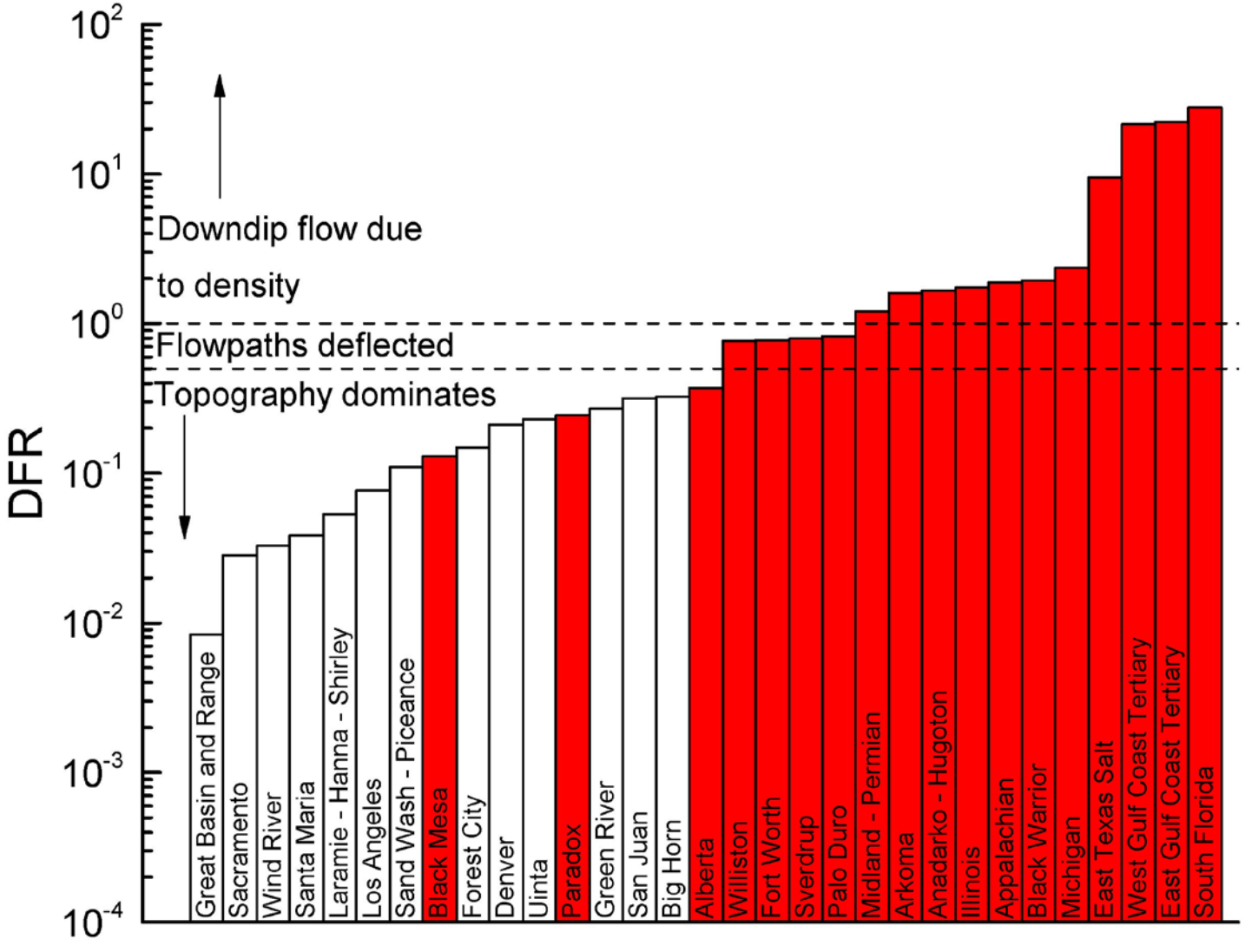
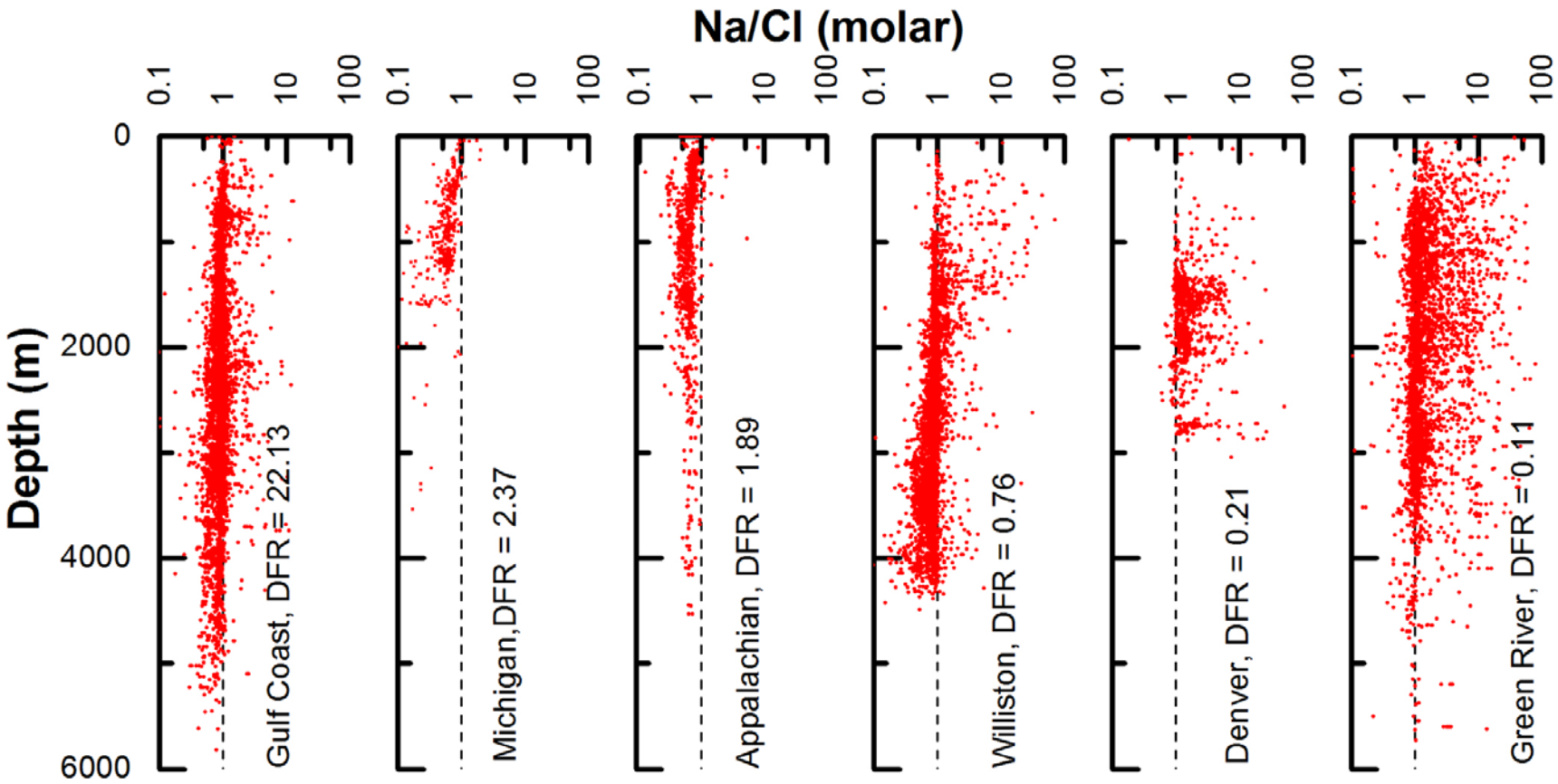
[1]Department of Civil, Geological and Environmental Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, [2]Department of Hydrology and Atmospheric Sciences, University of Arizona, Tucson, AZ, USA, [3]Geological Survey of Canada, Calgary, Alberta, Canada, [4]Department of Geological Sciences, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, [5]Bren School of Environmental Science and Management, University of California, Santa Barbara, CA, USA, [6]Geoscience Center, University of Göttingen, Göttingen, Germany

Abstract Brines are commonly found at depth in sedimentary basins. Many of these brines are known to be connate waters that have persisted since the early Paleozoic Era. Yet questions remain about their distribution and mechanisms for retention at depth in the Earth's crust. Here we demonstrate that there is insufficient topography to drive these dense fluids from the bottom of deep sedimentary basins. Our assessment based on driving force ratio indicates that sedimentary basins with driving force ratio > 1 contain connate waters and frequently host large evaporite deposits. These stagnant conditions appear to be relatively stable over geological time and insensitive to factors such as glaciations, erosion, compaction, and hydrocarbon generation.


Franklinian-
Sverdup
ΔH
ΔE
F
F
High density brine
Alberta
Williston
DFR
0.00 to 0.25
0.25 to 0.50
0.50 to 1.00
1.00 to 2.00
2.00 to 4.00
4.00 to 8.00
>8.00
Big Horn
Wind River
Great Basin
and Range
Green River
Uinta
Paradox
Sacramento
San Juan
Santa Maria
Black Mesa
Denver
Palo Duro
Anadarko - Hugoton
Forest City
Michigan
Illinois
Appalachian
Arkoma
Black Warrior
Fort Worth
East Texas Salt
Midland-
Permian
East Gulf Coast Tertiary
West Gulf
Coast Tertiary
South Florida


DFR
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
Downdip flow due
to density
Flowpaths deflected
Topography dominates
Great Basin and Range
Sacramento
Wind River
Santa Maria
Laramie - Hanna - Shirley
Los Angeles
Sand Wash - Piceance
Black Mesa
Forest City
Denver
Uinta
Paradox
Green River
San Juan
Big Horn
Alberta
Williston
Fort Worth
Sverdrup
Palo Duro
Midland - Permian
Arkoma
Anadarko - Hugoton
Illinois
Appalachian
Black Warrior
Michigan
East Texas Salt
West Gulf Coast Tertiary
East Gulf Coast Tertiary
South Florida

- Basins with high DFR have chemistry indicating marine source at depth
- Basins with low DFR and shallower portions of high DFR basins have salinity from dissolution



Questioning whether Sr, Br, Cl, I isotopes to understand origin of salinity and historical solute transport in the Williston Basin

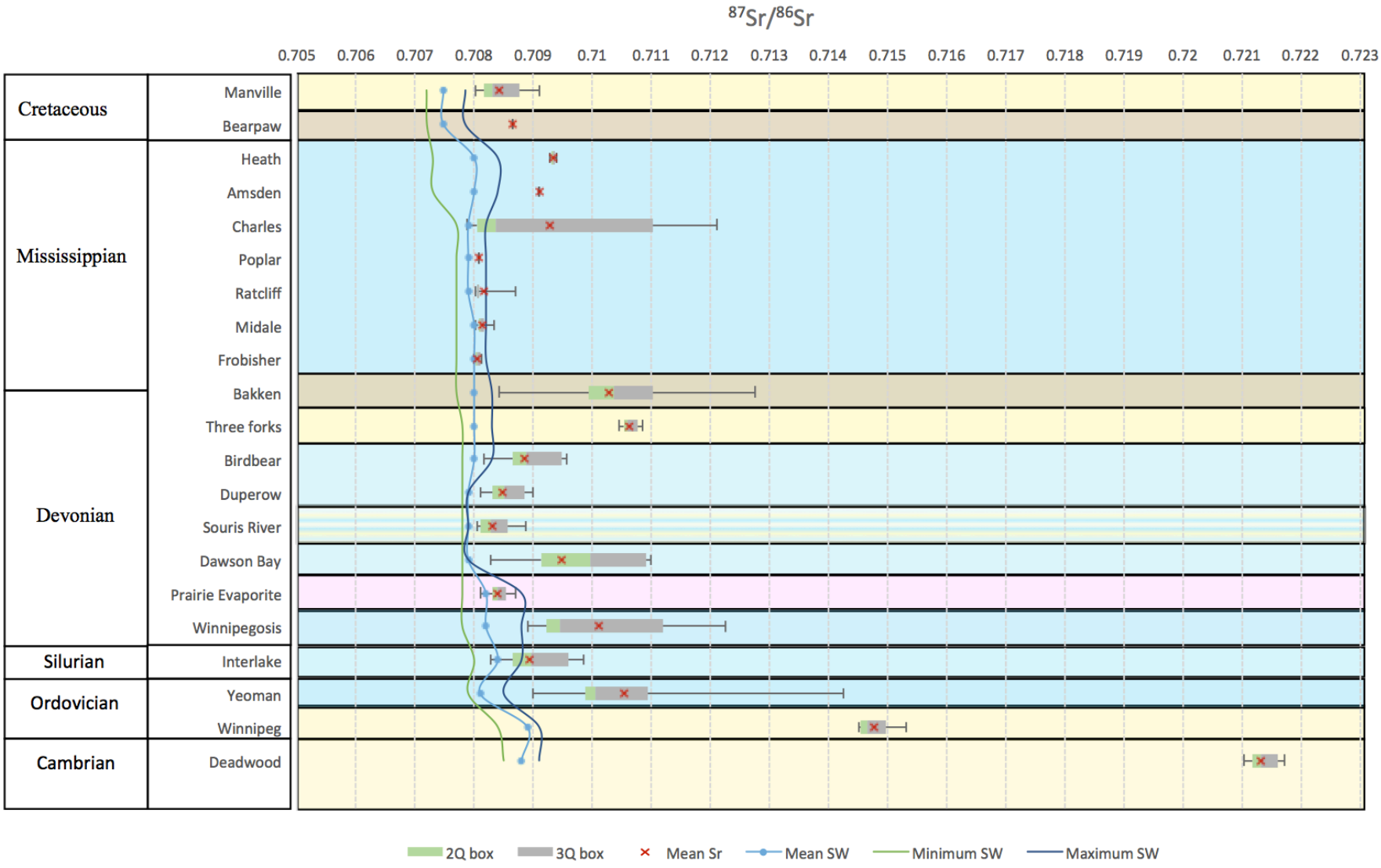
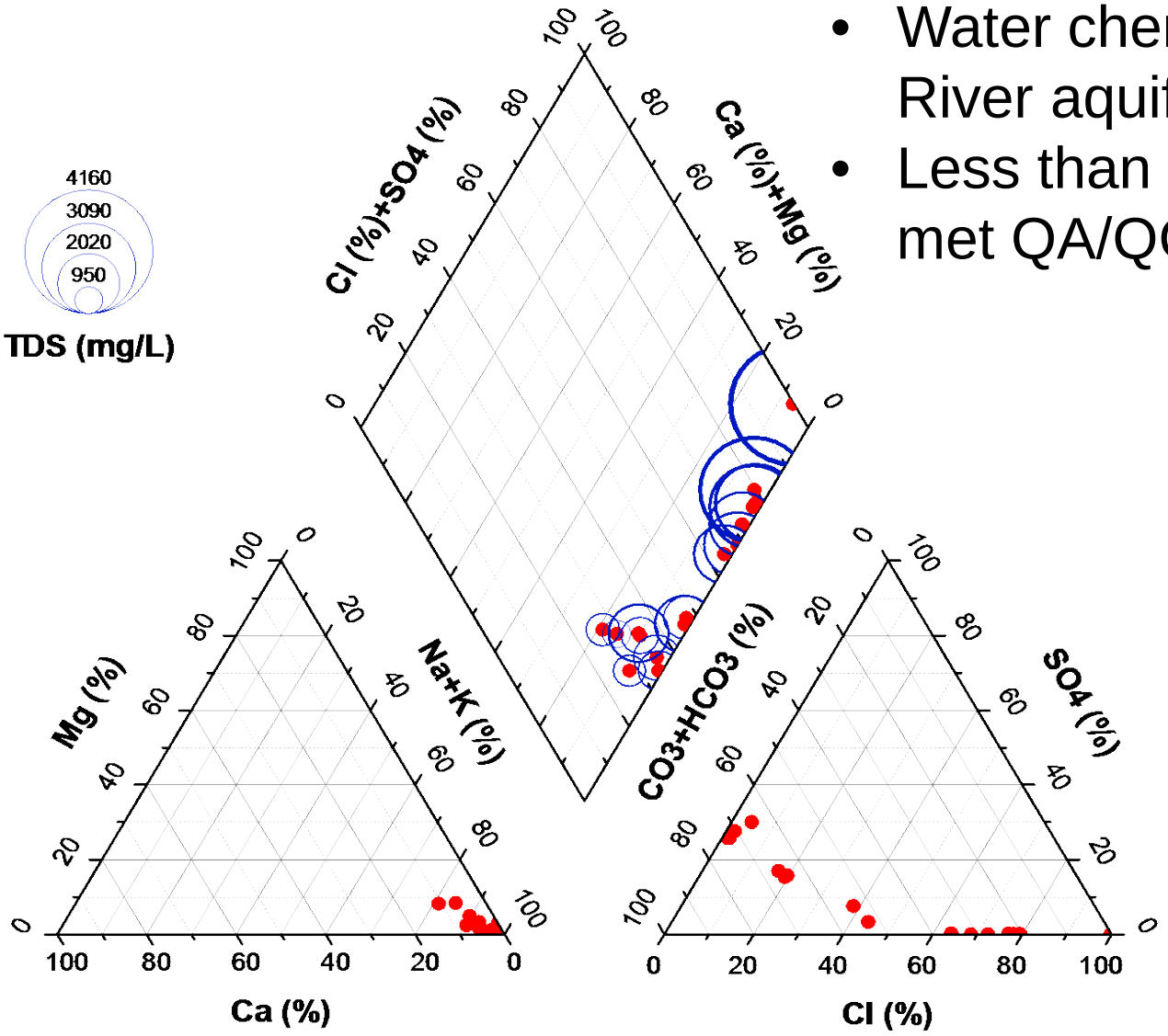


Figure by M. Marza, U. Arizona

Intermediate aquifers are data scarce.

- Water chemistry for the Judith River aquifer in Saskatchewan.
- Less than 4% of samples that met QA/QC criteria.



From Ferris et al., 2017

nature geoscience

ARTICLES

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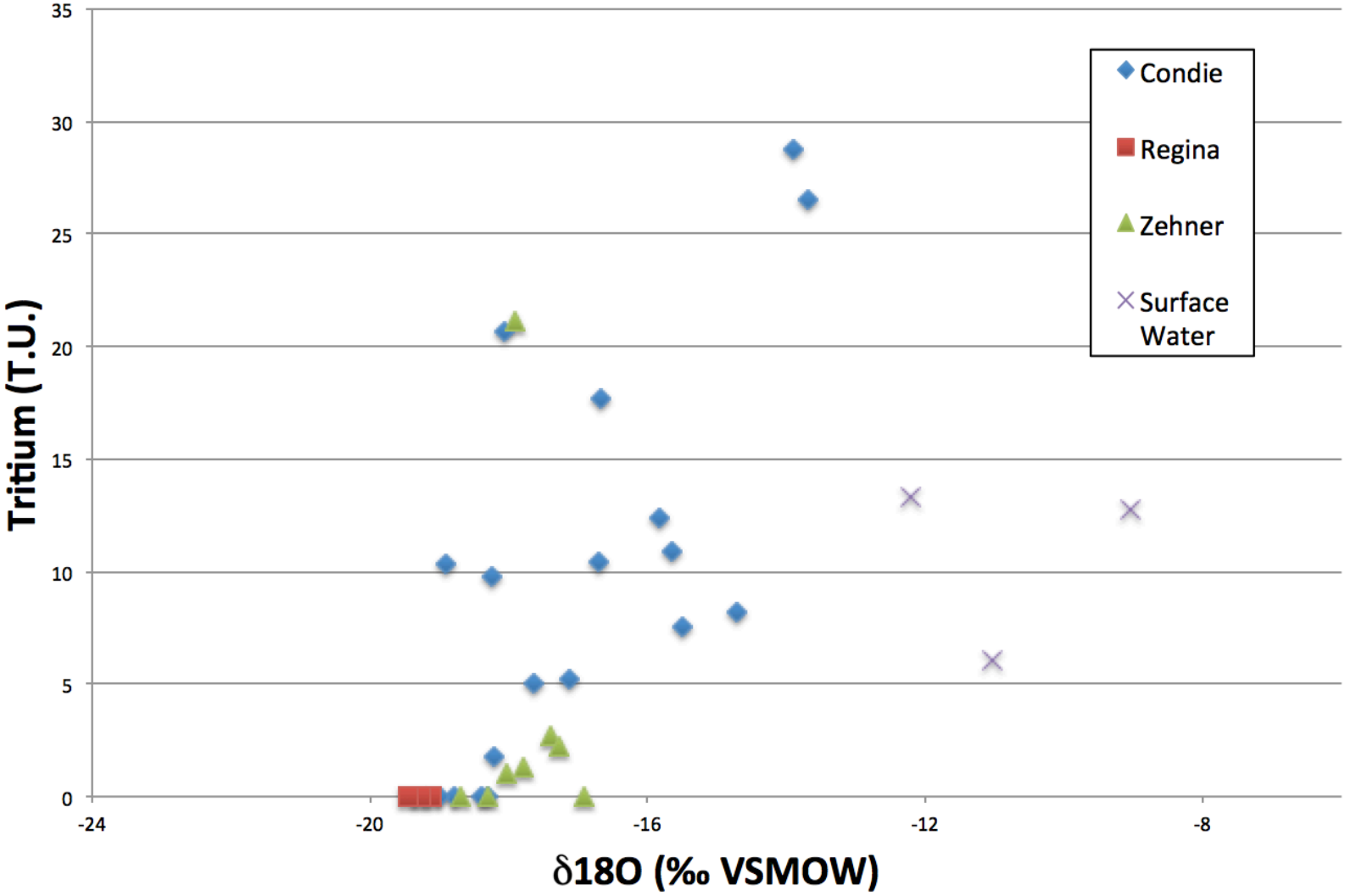
Global aquifers dominated by fossil groundwaters but wells vulnerable to modern contamination

Scott Jasechko[1*], Debra Perrone[2,3], Kevin M. Befus[4], M. Bayani Cardenas[5], Grant Ferguson[6], Tom Gleeson[7], Elco Luijendijk[8], Jeffrey J. McDonnell[9,10,11], Richard G. Taylor[12], Yoshihide Wada[13,14] and James W. Kirchner[15,16,17]

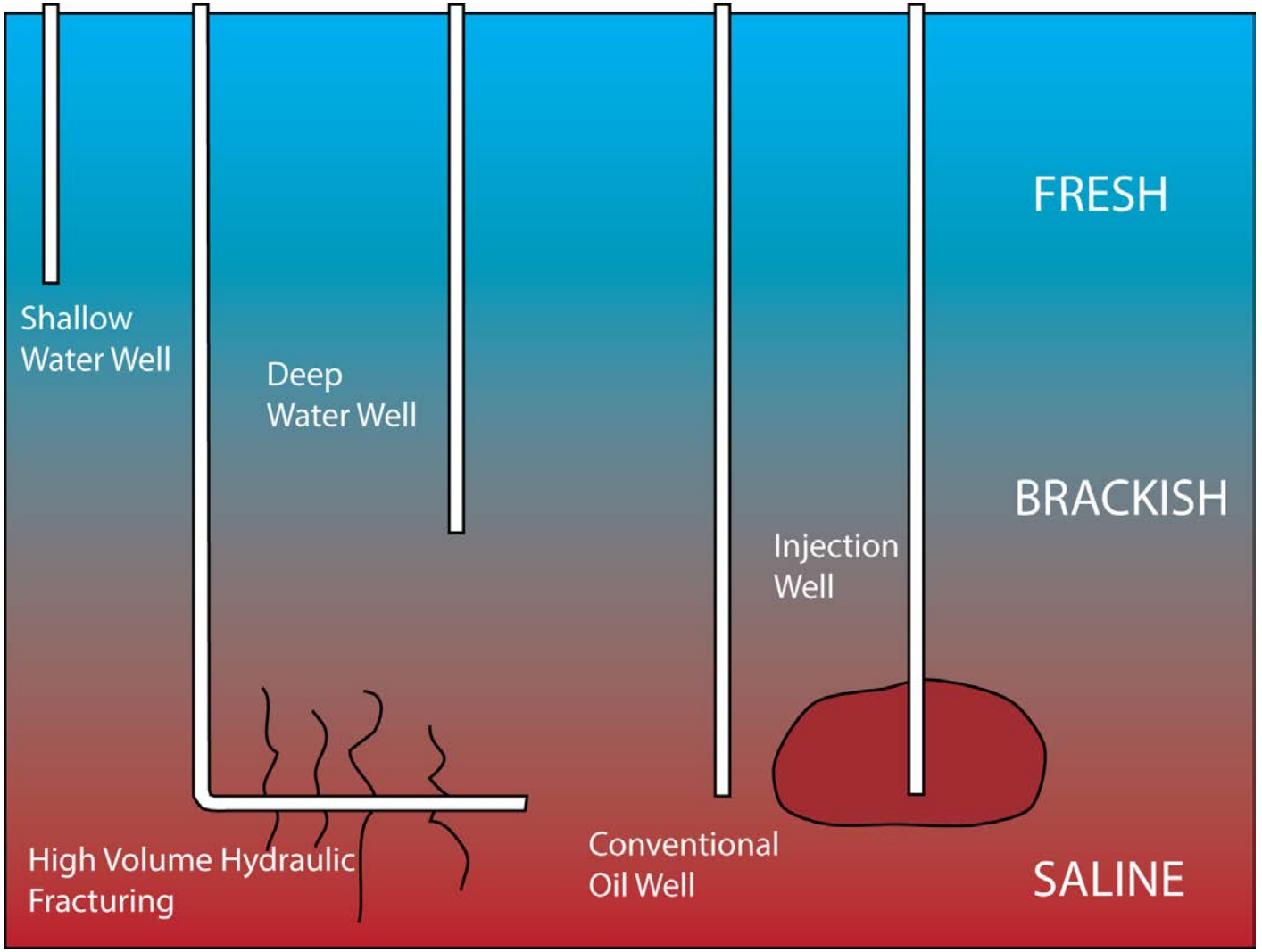
The vulnerability of groundwater to contamination is closely related to its age. Groundwaters that infiltrated prior to the Holocene have been documented in many aquifers and are widely assumed to be unaffected by modern contamination. However, the global prevalence of these 'fossil' groundwaters and their vulnerability to modern-era pollutants remain unclear. Here we analyse groundwater carbon isotope data (^{12}C, ^{13}C, ^{14}C) from 6,455 wells around the globe. We show that fossil groundwaters comprise a large share (42–85%) of total aquifer storage in the upper 1 km of the crust, and the majority of waters pumped from wells deeper than 250 m. However, half of the wells in our study that are dominated by fossil groundwater also contain detectable levels of tritium, indicating the presence of much younger, decadal-age waters and suggesting that contemporary contaminants may be able to reach deep wells that tap fossil aquifers. We conclude that water quality risk should be considered along with sustainable use when managing fossil groundwater resources.

Mixing of young and old fresh groundwater shown by isotopes in the East Regina aquifer system



Data courtesy of Kei Lo, SWSA

Competition for pore space is a threat to water security



Cretaceous marine sediments may be the key to groundwater protection in Western Canada.

Photo from John Woodsé/Canadian Press

Summary

- More anthropogenic “recharge” than natural
- More data than previously
- Several classes of groundwater in terms of age and chemistry
- Looking for opportunities to translate our experience to other basins, especially those new to oil and gas development

Winnipeg Formation at Black Island (Photo from Manitoba Museum)