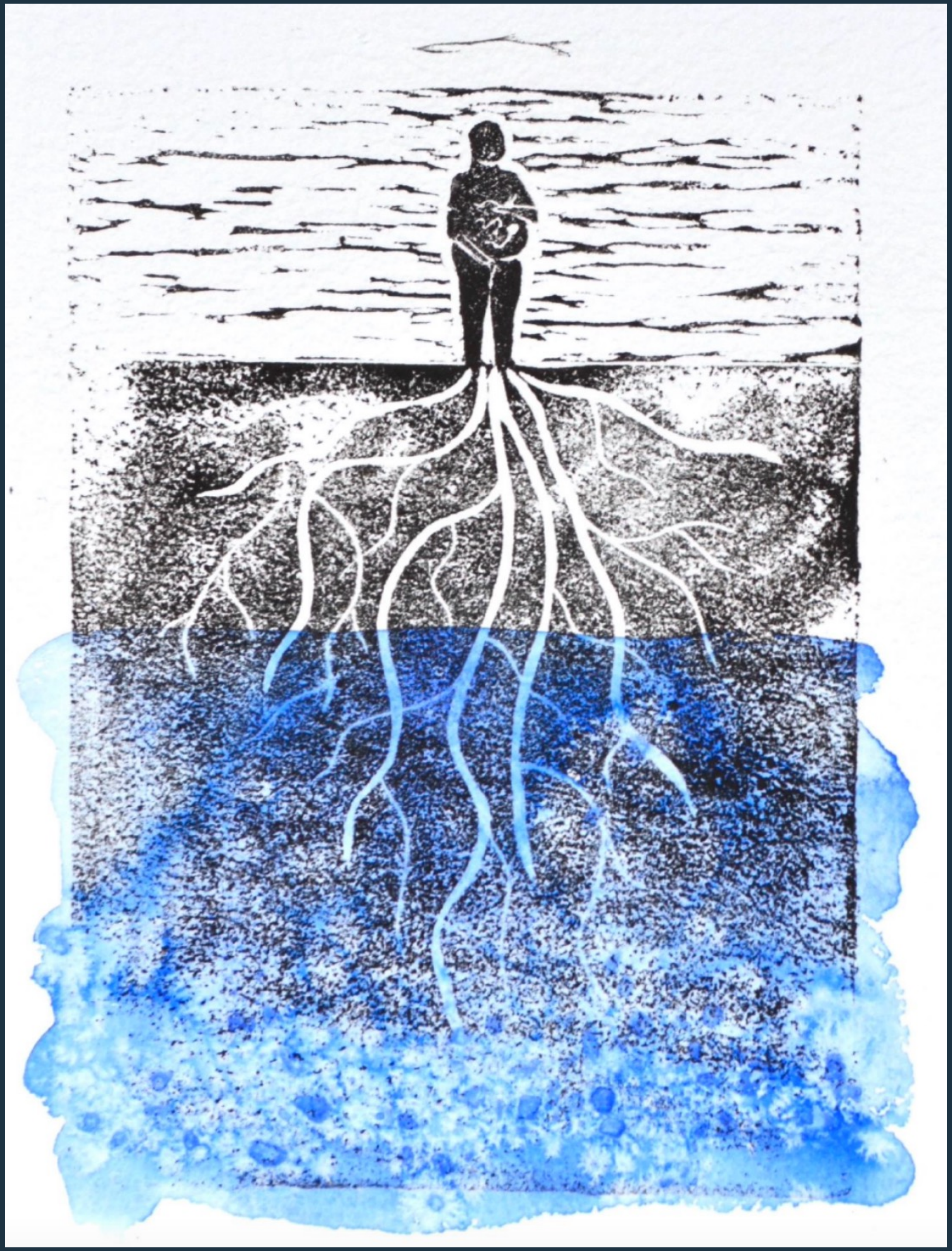


“Connections” from *Deep Time* by Louise Arnal

University of Saskatchewan

Deep Groundwater – The Bottom of the Hydrologic Cycle

10 GIWS YEARS 2011-2021

Grant Ferguson
Civil, Geological & Environmental Engineering/
School of Environment & Sustainability

Deep Groundwater

Key questions

- How much groundwater is there?
- How deep does it circulate?
- How connected is deep groundwater to the rest of the hydrologic cycle?
- Can we use older groundwater?
- How have deep groundwater systems changed over long time periods?

Water Resources Research

COMMENTARY

10.1029/2019WR026010

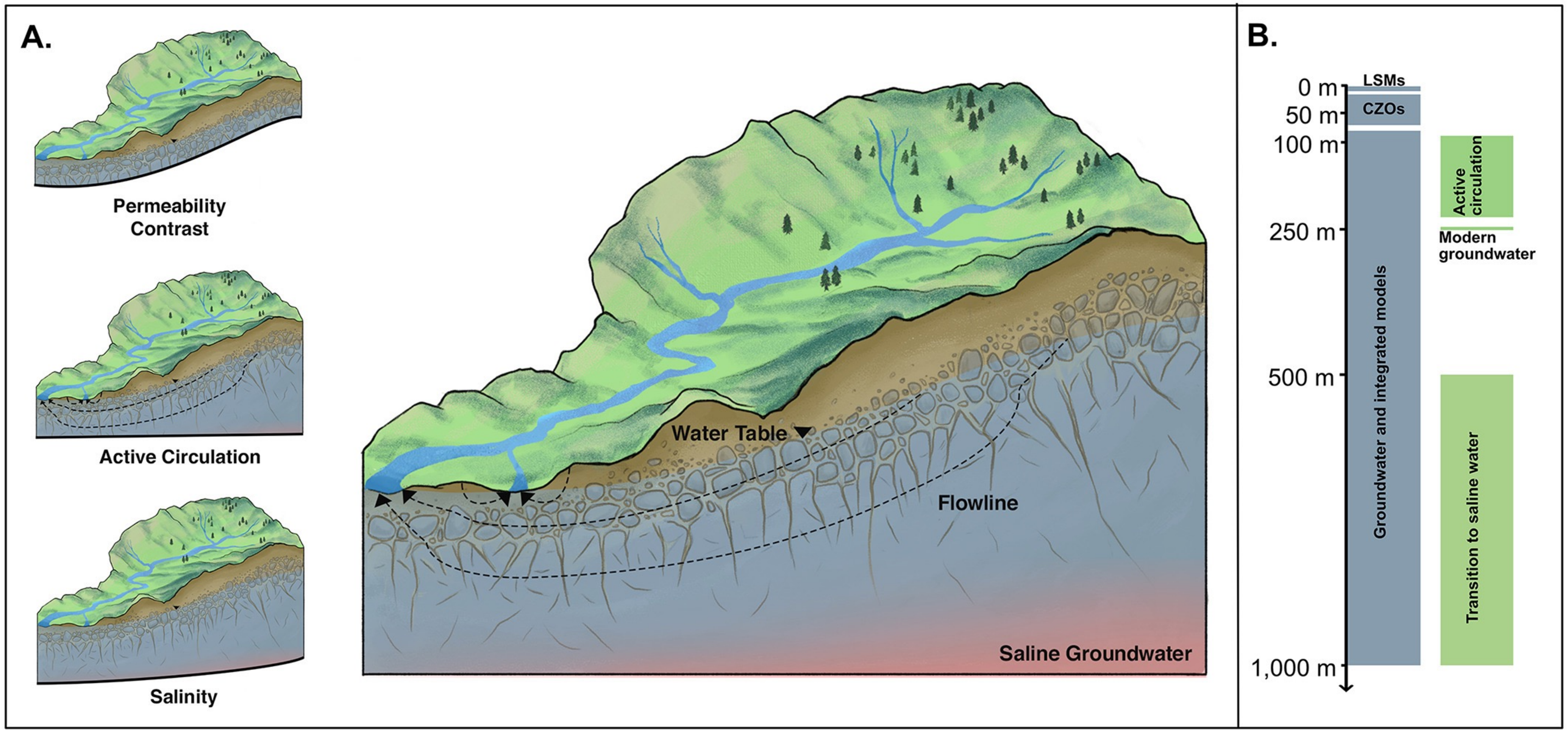
Key Points:

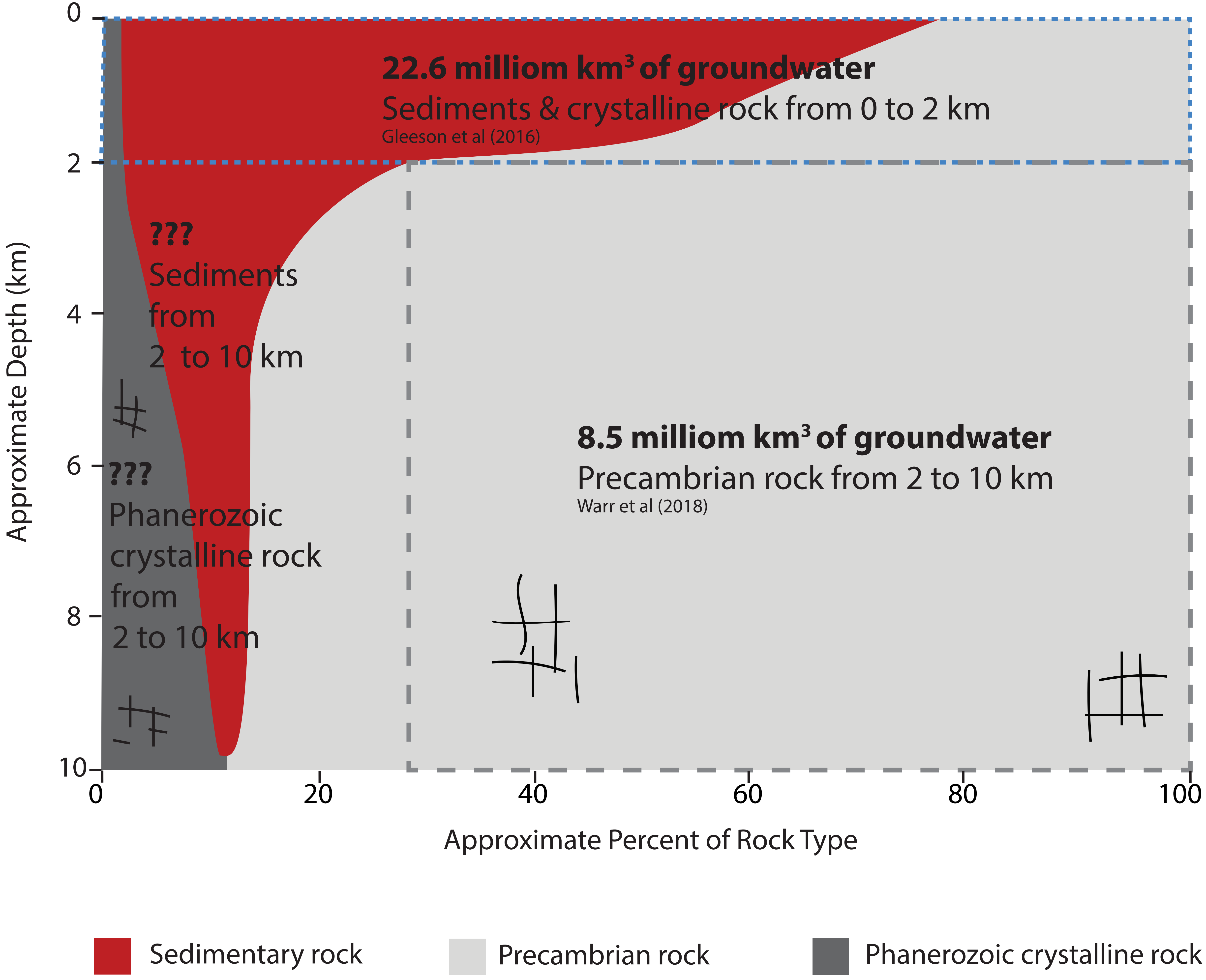
- Methods for defining the bottom of a watershed vary greatly across the hydrologic community
- Improved communication and collaborative efforts between the catchment hydrology and hydrogeology communities are needed

Where Is the Bottom of a Watershed?

Laura E. Condon[1], Katherine H. Markovich[1], Christa A. Kelleher[2], Jeffrey J. McDonnell[3,4], Grant Ferguson[3,5], and Jennifer C. McIntosh[1]

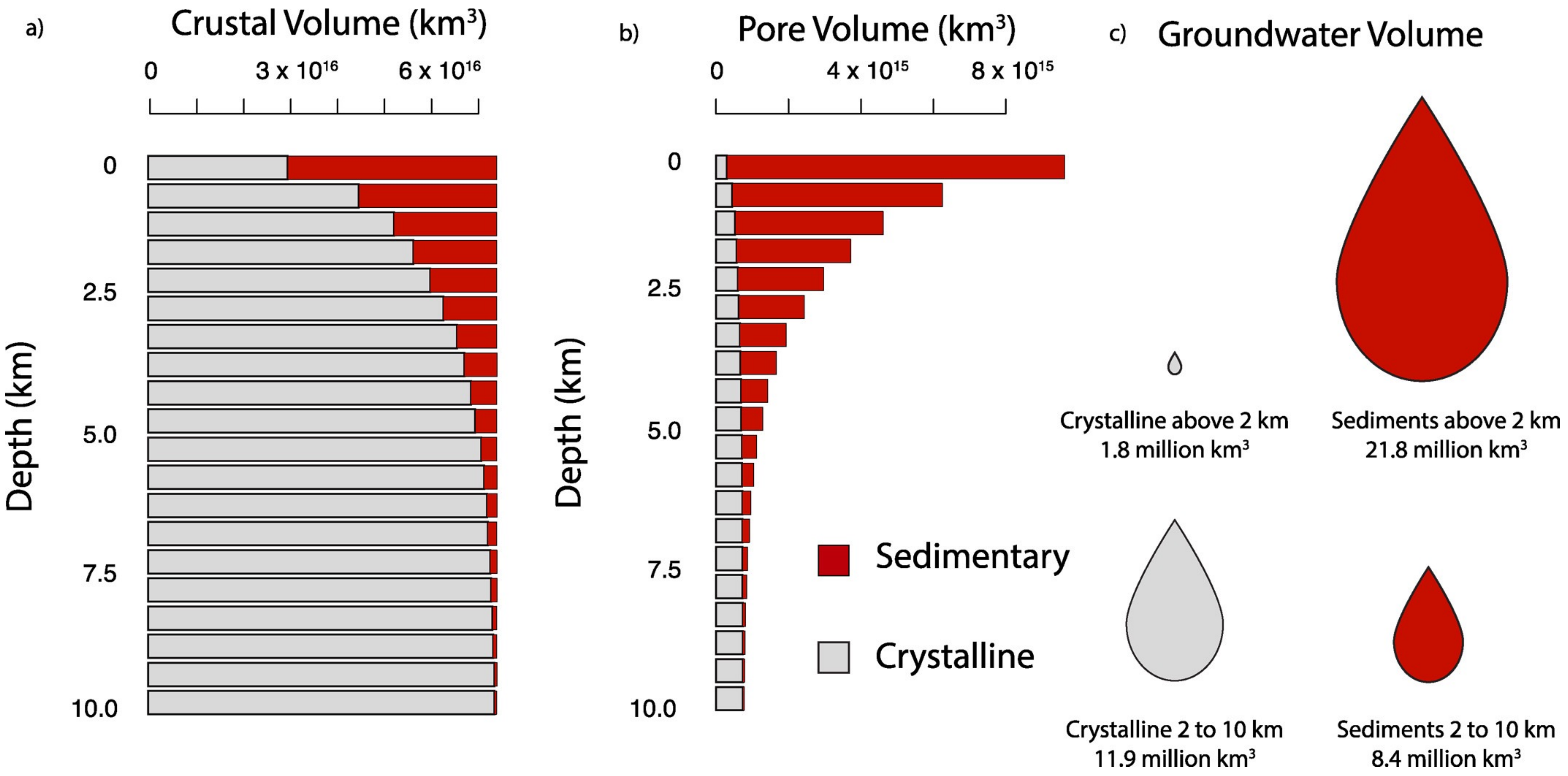
[1]Department of Hydrology and Atmospheric Sciences, University of Arizona, Tucson, AZ, USA, [2]Department of Earth Sciences, Syracuse University, Syracuse, NY, USA, [3]School of Environment and Sustainability, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, [4]School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, UK, [5]Department of Civil, Geological and Environmental Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, Canada



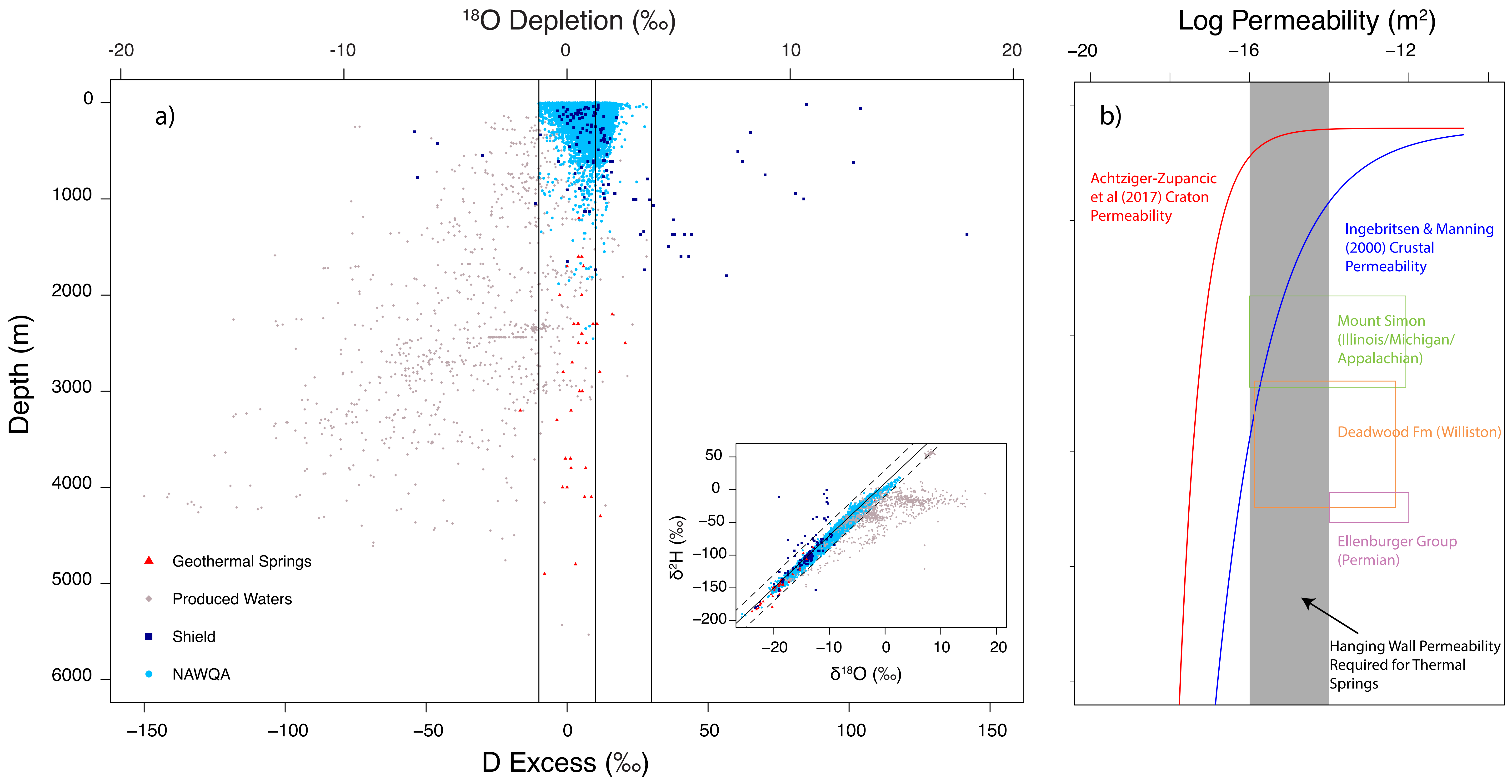


What is the total volume of groundwater?

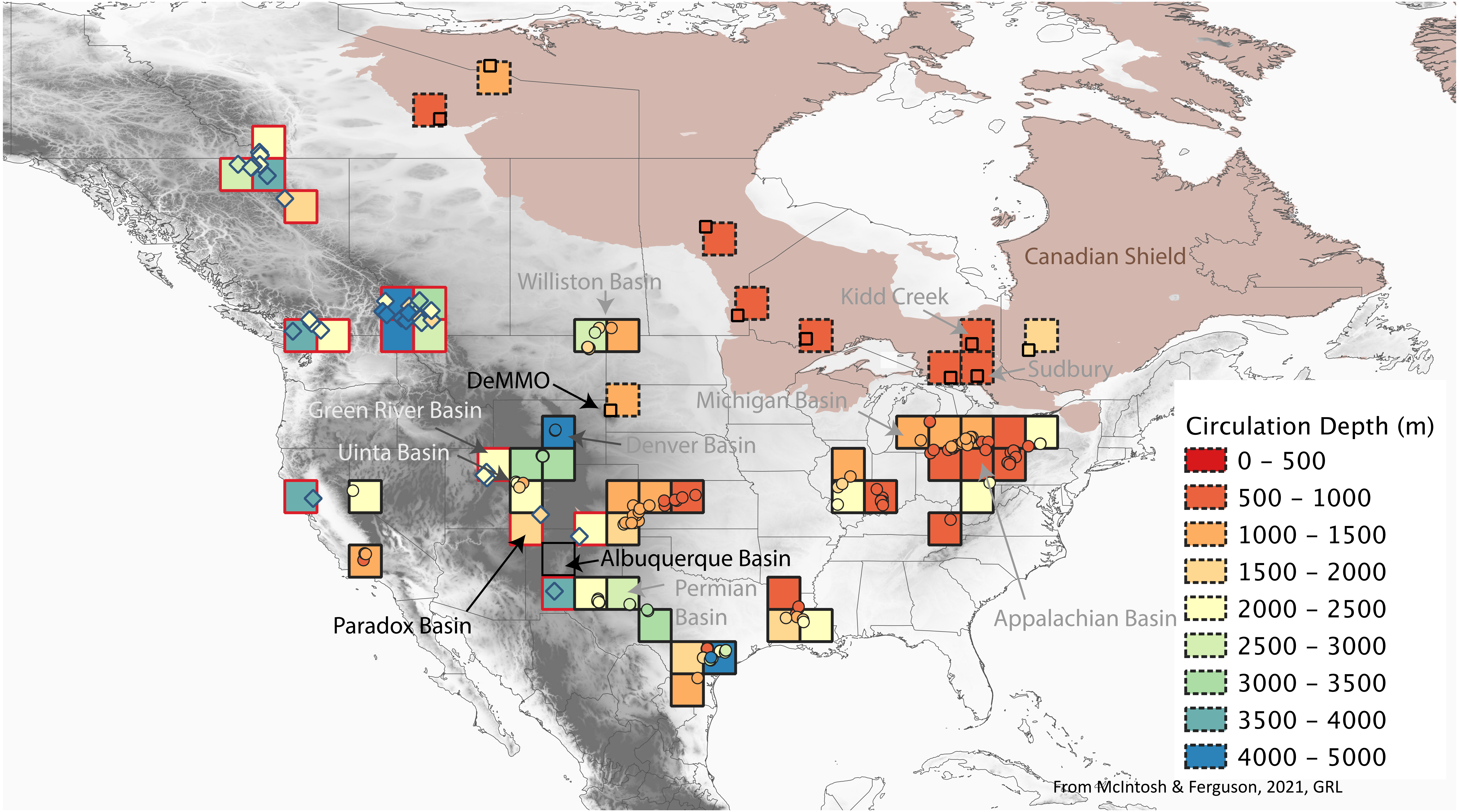
From Ferguson, McIntosh et al., 2021, GRL

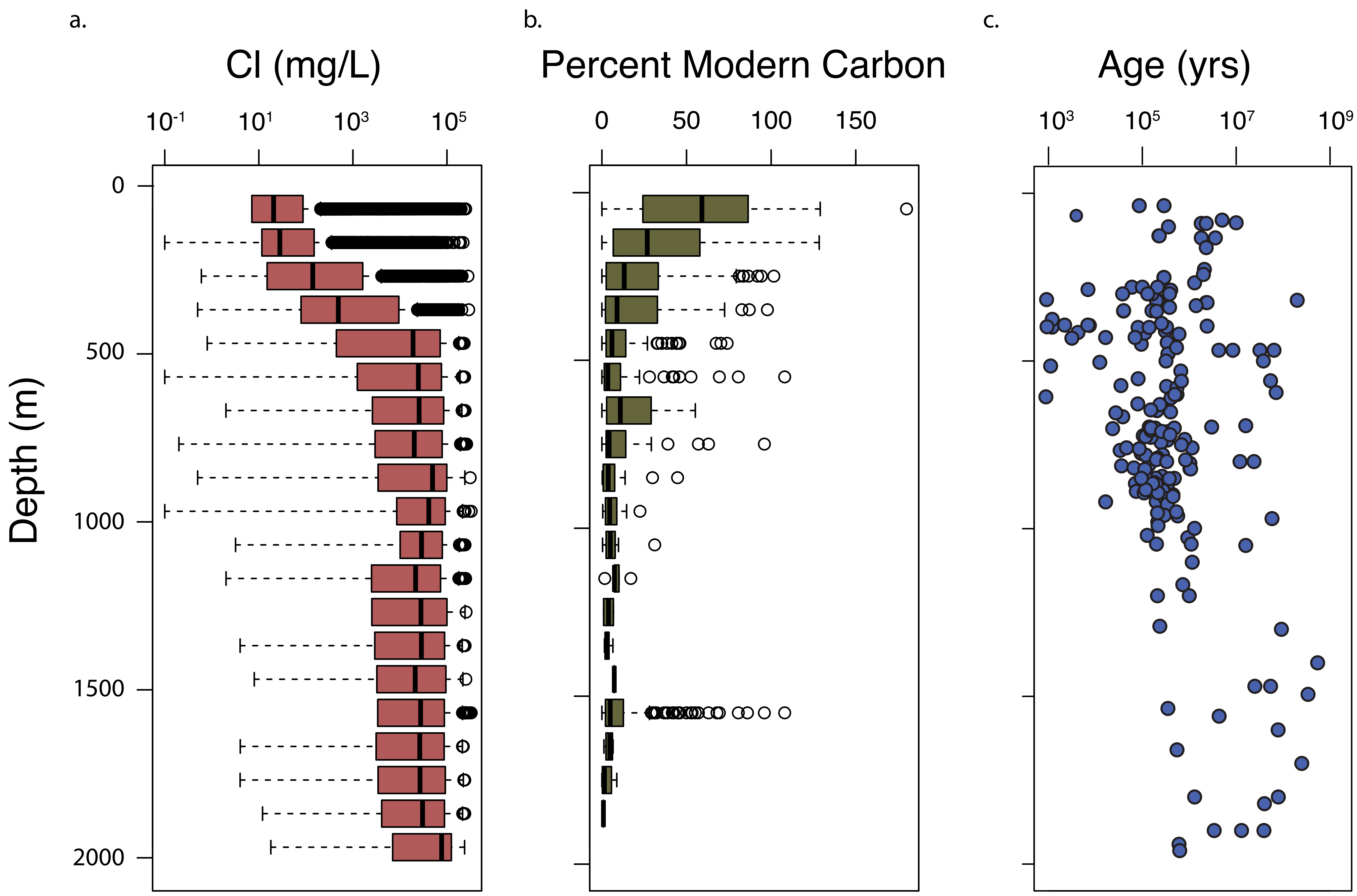


From Ferguson, McIntosh et al., 2021, GRL

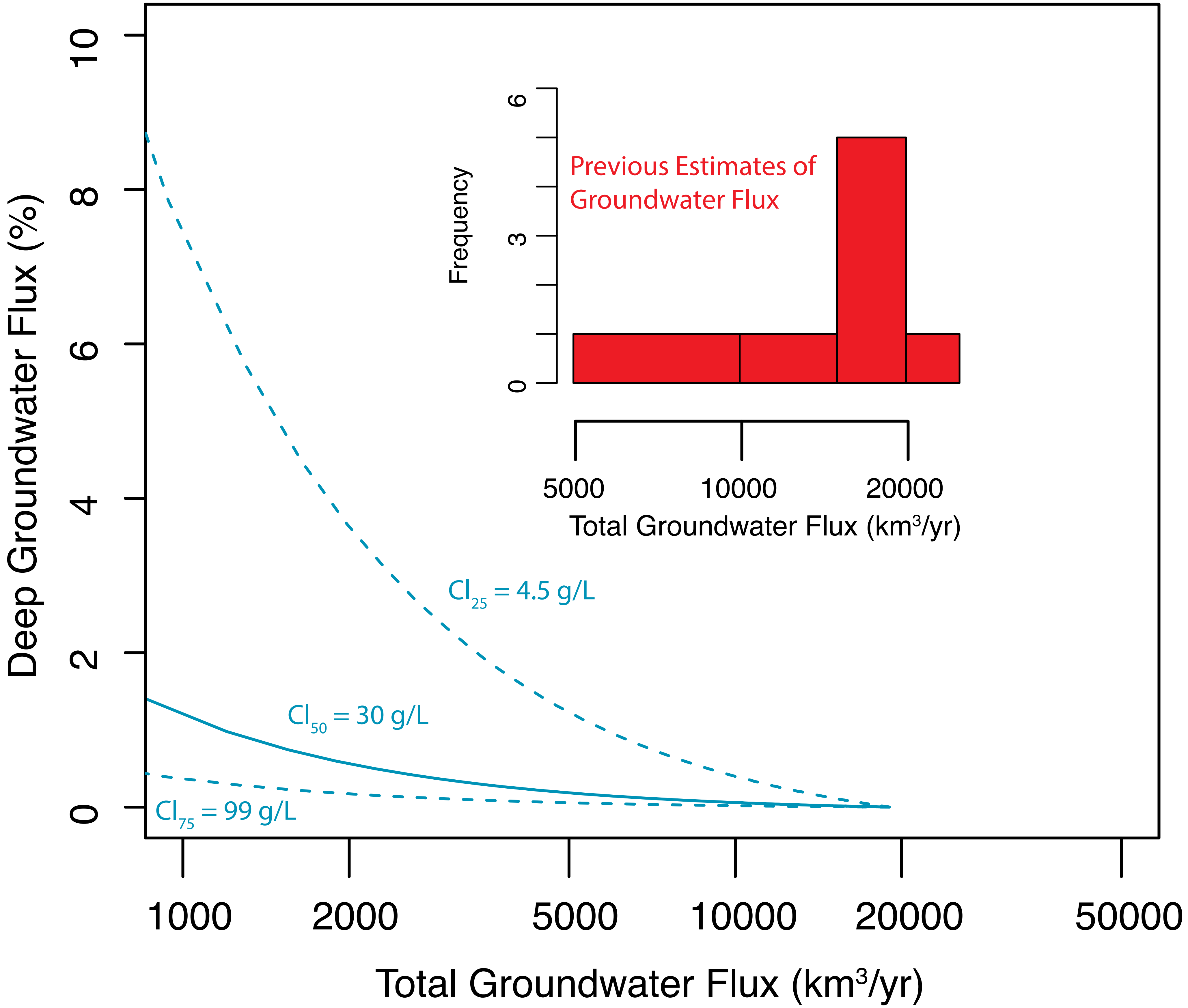


From McIntosh & Ferguson, 2021, GRL


Canadian Shield
Williston Basin
Kidd Creek
Sudbury
DeMMO
Michigan Basin
Green River Basin
Denver Basin
Uinta Basin
Albuquerque Basin
Permian Basin
Paradox Basin
Appalachian Basin
Circulation Depth (m)
0 – 500
500 – 1000
1000 – 1500
1500 – 2000
2000 – 2500
2500 – 3000
3000 – 3500
3500 – 4000
4000 – 5000
From McIntosh & Ferguson, 2021, GRL



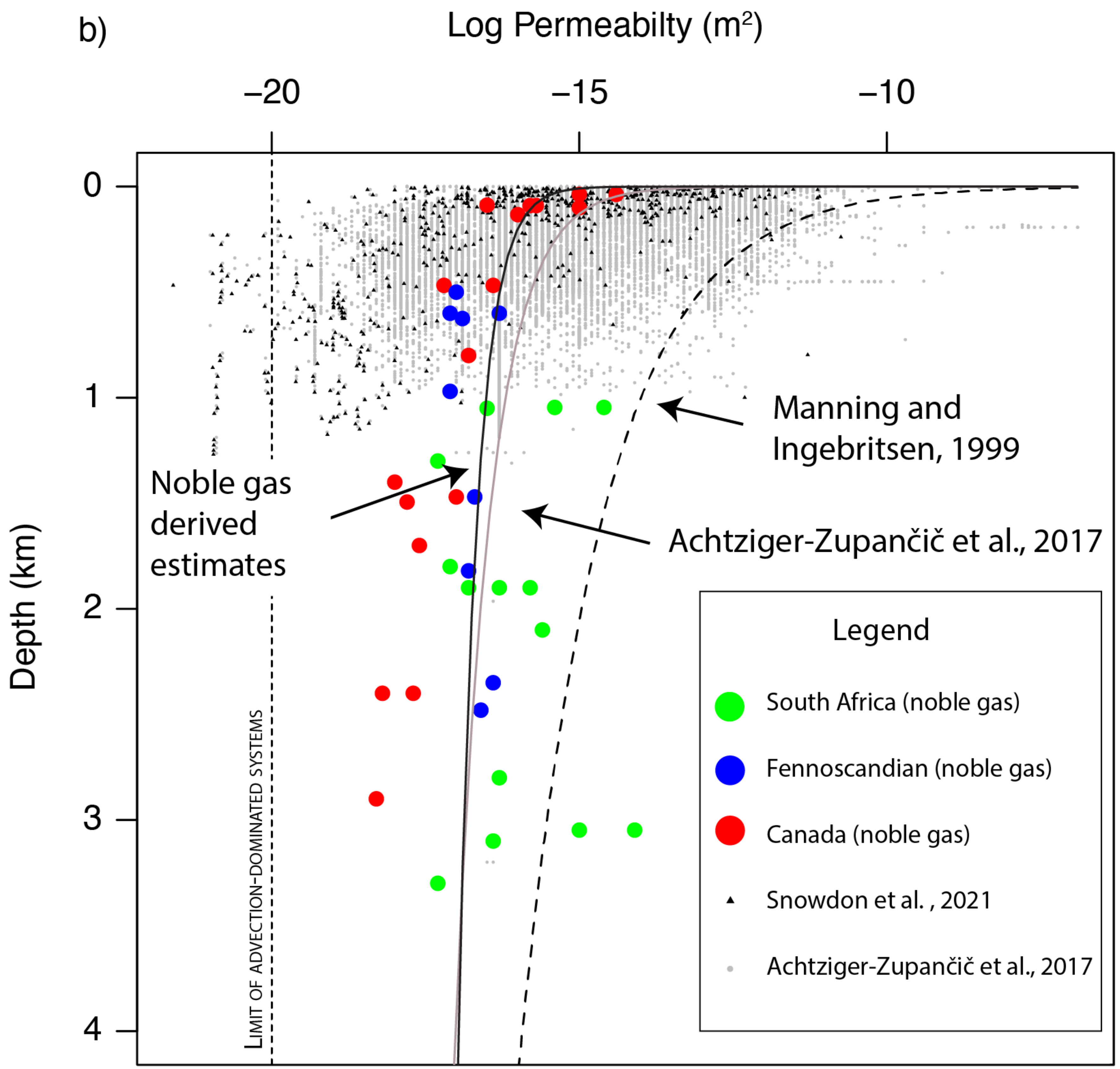
From Ferguson, McIntosh et al., in prep



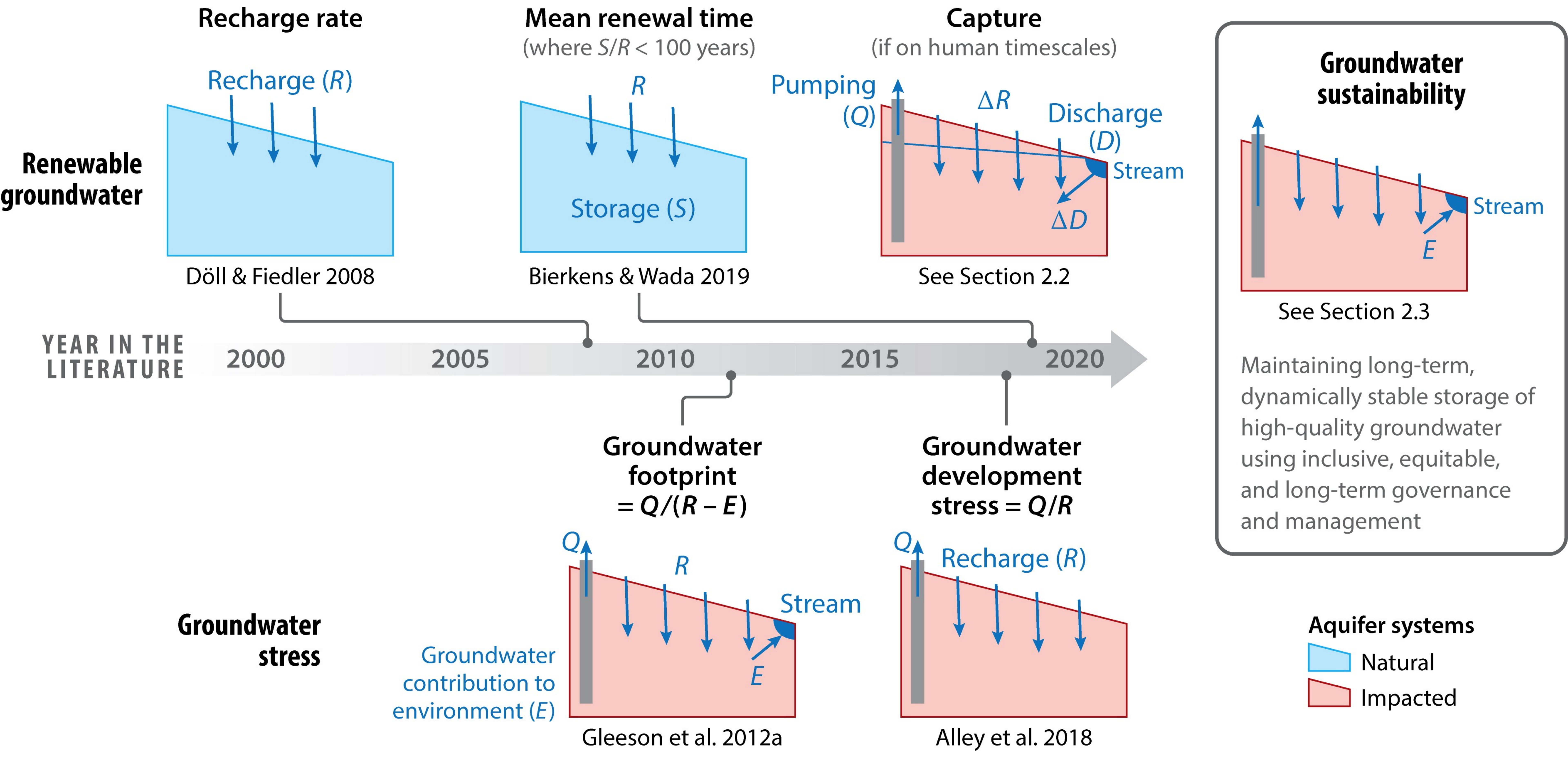
Chloride fluxes in global streamflow suggest minimal connection between deeper groundwaters and the rest of the hydrologic cycle and hint at overestimation of global groundwater recharge.

From Ferguson, McIntosh et al., in prep

New permeability estimates from residence times suggest that previous estimates of were too high



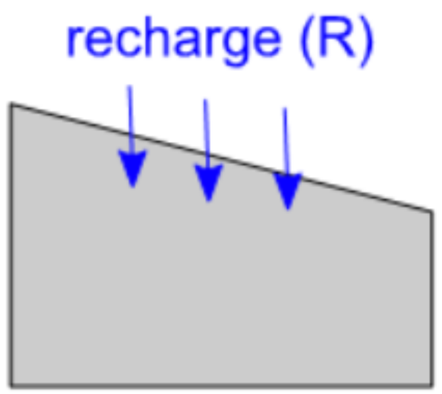
From Ferguson, McIntosh, Warr & Sherwood Lollar, in prep



Gleeson T, et al. 2020.
Annu. Rev. Earth Planet. Sci. 48:431–63

Existing definitions of renewable groundwater:

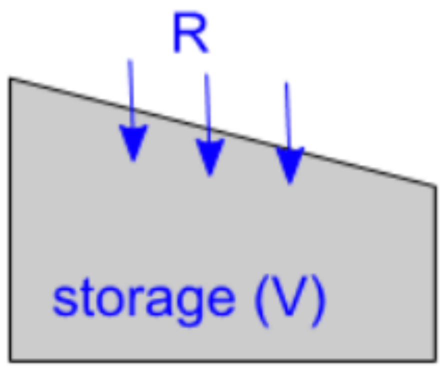
1. Flux based: 'balance of fluxes' => recharge



(e.g. FAO 2003)

Problems:
- Ignores capture
- Ignores storage renewal timeframe

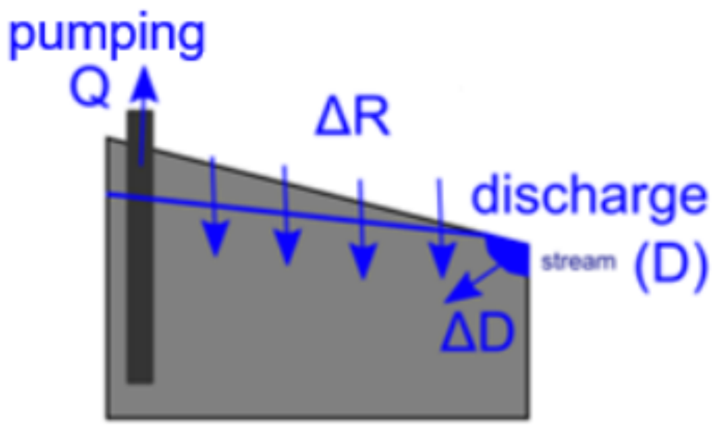
2. Storage based: 'mean renewal time' => V/R <100 years



(e.g. Margat et al. 2006)

Problems:
- Ignores capture
- Considers renewal time of whole aquifer not just the 'depleted' fraction

3. Capture if on human timescale



(e.g. Gleeson et al. 2020)

Problems:
- 'Blames' the resource not the user

We propose that:

Renewable groundwater use allows for dynamically stable re-equilibrium of groundwater levels and quality on human timescales (~50-100 years).

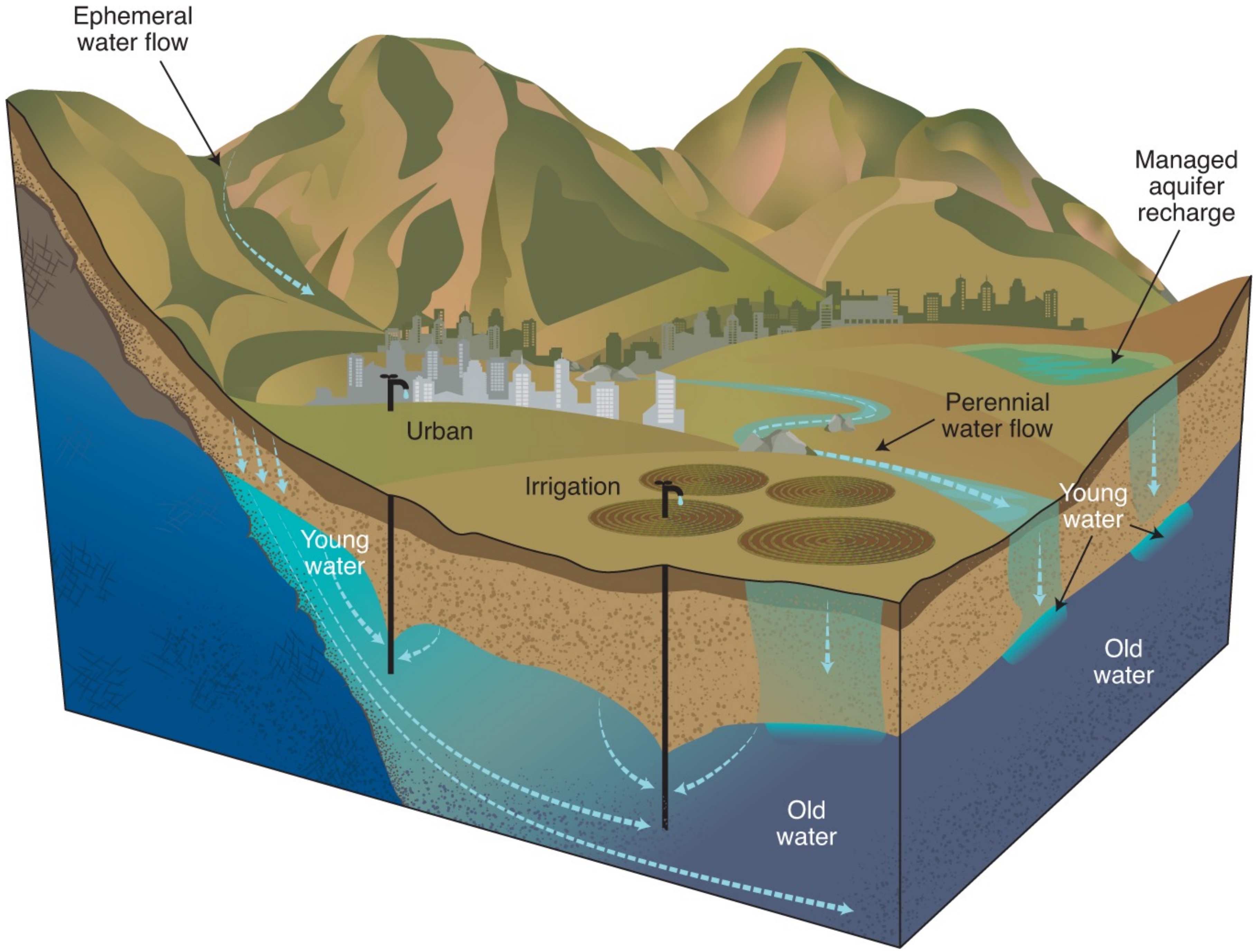
From Cuthbert, Gleeson, Bierkens, Ferguson & Taylor, In review, WRR

Check for updates

Rethinking groundwater age

It is commonly thought that old groundwater cannot be pumped sustainably, and that recently recharged groundwater is inherently sustainable. We argue that both old and young groundwaters can be used in physically sustainable or unsustainable ways.

Grant Ferguson, Mark O. Cuthbert, Kevin Befus, Tom Gleeson and Jennifer C. McIntosh



AGU ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER

10.1029/2021GL097618

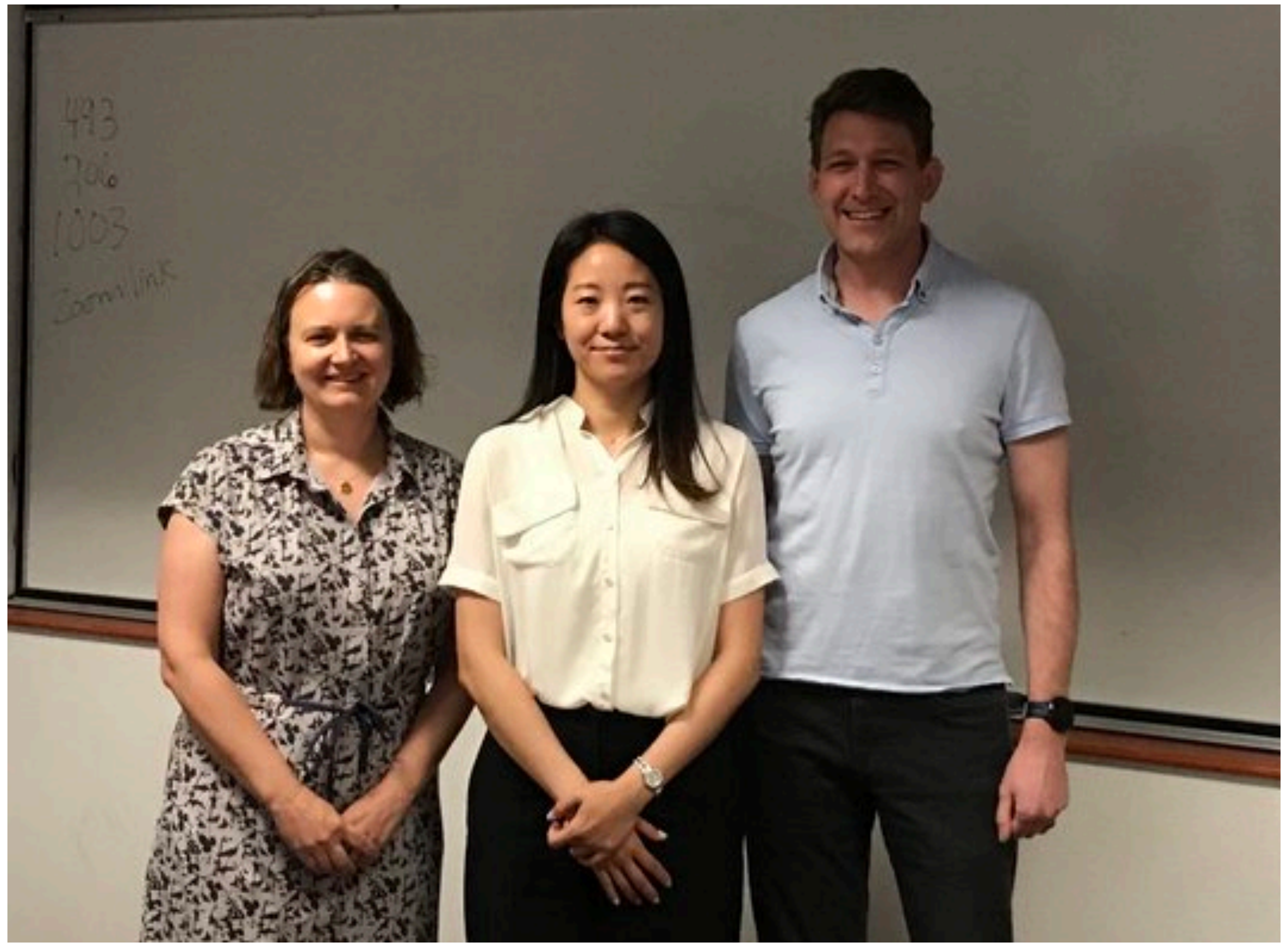
Key Points:

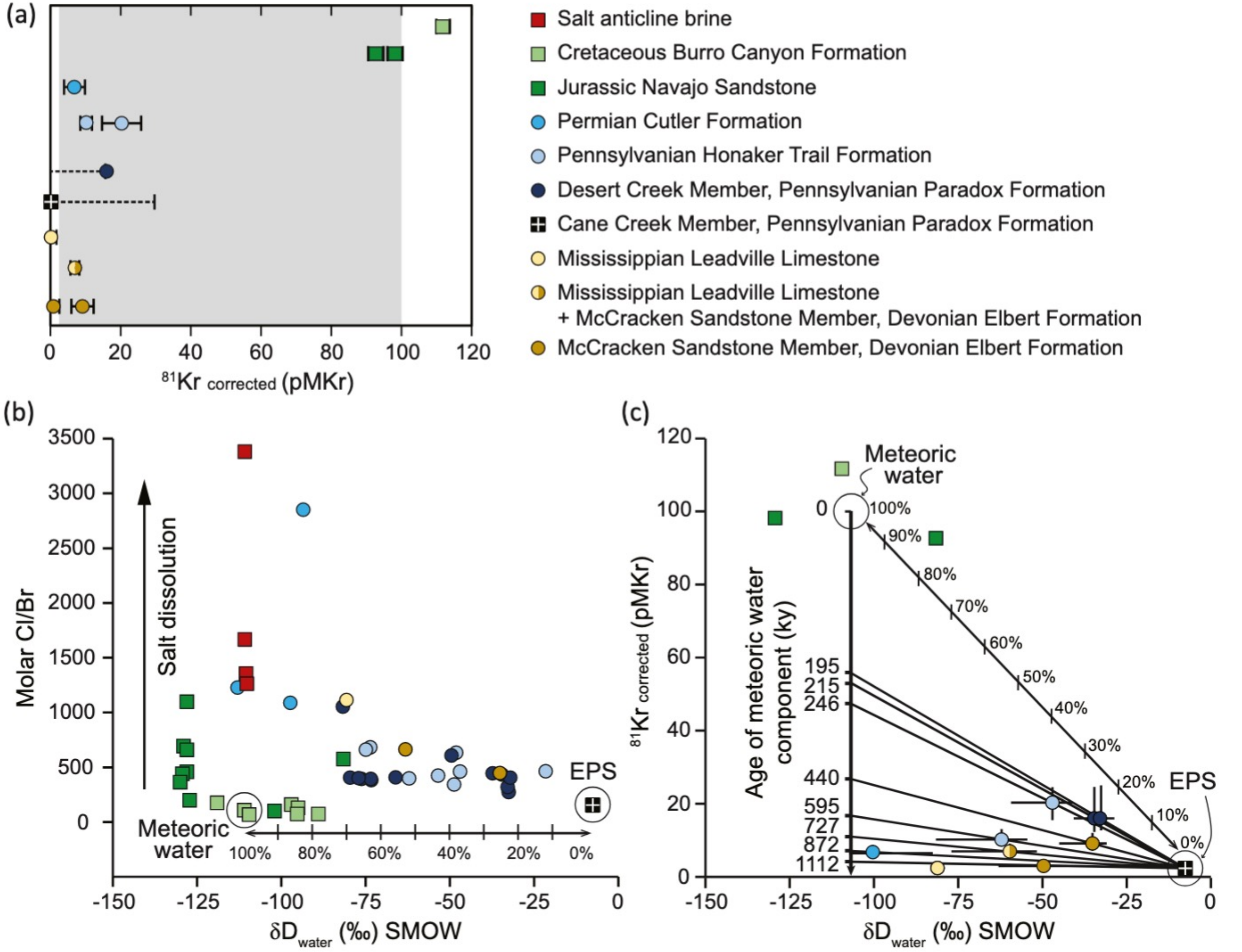
- Meteoric waters up to 3 km in basinal aquifers are <1.1 Ma
- Recent, rapid denudation of the Colorado Plateau enabled deep circulation of meteoric water and flushing of connate brines
- Krypton-81 dating can illuminate the timescales and extent of meteoric circulation in response to geologic and/or climatic forcings

Krypton-81 Dating Constrains Timing of Deep Groundwater Flow Activation

Ji-Hyun Kim[1], Grant Ferguson[1,2], Mark Person[3], Wei Jiang[4], Zheng-Tian Lu[4], Florian Ritterbusch[4], Guo-Min Yang[4], Rebecca Tyne[5,6], Lydia Bailey[7], Chris Ballentine[5], Peter Reiners[7], and Jennifer McIntosh[1,2]

[1]Department of Hydrology and Atmospheric Sciences, University of Arizona, Tucson, AZ, USA, [2]Department of Civil, Geological and Environmental Engineering, University of Saskatchewan, Saskatoon, SK, Canada, [3]Department of Earth and Environmental Science, New Mexico Tech, Socorro, NM, USA, [4]School of Physics, University of Science and Technology of China, Hefei, China, [5]Department of Earth Sciences, University of Oxford, Oxford, UK, [6]Now at Woods Hole Oceanographic Institution, Falmouth, MA, USA, [7]Department of Geosciences, University of Arizona, Tucson, AZ, USA





Current sampling program for noble gases and radiocarbon in Saskatchewan to establish paleohydrology of Pleistocene sediments.

Thank you!

UNIVERSITY OF SASKATCHEWAN

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