Development of a Geochemical Tool for Sourcing Leaking Well Fluids in Southwestern Ontario*

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Abstract

Abandoned hydrocarbon wells in southwestern Ontario can act as conduits for sulphur water, brines, and hydrocarbons from intermediate to deep Paleozoic bedrock aquifers. Such leakage may pose a threat to shallow groundwater aquifers and the surface environment. Cost-effective plugging of these wells requires knowledge of the sources of the leaking fluids. This study characterizes the isotopic compositions (δ¹⁸O, δ¹⁸H₂O, δ¹⁸H₂O, δ¹³CDIC, ²⁸Sr/²⁶Sr, δ³⁷Cl and δ³⁸Br) of groundwater in the region, which show distinctive differences between bedrock formations, allowing determination of unique ‘fingerprints’ of each formation. The geochemical data also improve our understanding of groundwater origin and evolution. A brackish to saline aquifer system containing dissolved H₂S is present at intermediate depths of up to 450m, recharged by down-dip infiltration of meteoric water from shallow fresh water aquifers. At greater depths, a series of confined brine aquifers contain residual evaporated Paleozoic seawater, modified by rock-water interaction and other processes. A Bayesian mixing model, SIAR, was applied to these data to develop a tool for identifying the source(s) of leaking fluids. This model determines the possible range of proportions for each source and the probability distribution therein; hypothetical test mixtures and a few real-world examples indicate that it is able to predict proportions with acceptable accuracy.

References Cited


Development of a geochemical tool for sourcing leaking well fluids in southwestern Ontario

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- SIAR creators (A. Parnell et al.)
Project overview – The Problem

• Legacy of abandoned O&G wells
• Corroded casings can act as fluid conduits between deep aquifers and surface
• MNR’s AWP – effort to plug these wells
  – Often lack well records, original depth unknown
Geochemical tool

• Previous research suggested that significant isotopic differences exist between units’ fluids
  – Possible use for identifying leaking fluid sources?

• Project goals:
  – Expand existing unit characterization
    • $\delta^{18}$O and $\delta^2$H of H$_2$O
    • $\delta^{34}$S and $\delta^{18}$O of SO$_4^{2-}$
    • $\delta^{13}$C of DIC
    • $^{87}$Sr/$^{86}$Sr
    • $\delta^{37}$Cl and $\delta^{81}$Br
  – Develop a statistical tool for assessing fluid origins

from Dollar et al. (1991)
Results - Water Isotopes

- Deep aquifers (~500-1200m)
- Salina A-2 unit
- Salina A-1 unit
- Guelph
- Clinton-Cataract
- Trenton-Black River
- Cambrian

δ¹⁸O ‰ (VSMOW)
δ²H ‰ (VSMOW)

GLWML = Great Lakes Meteoric Water Line
mixed with meteoric water
Strontium Isotopes
Cl and Br isotopes

- Dundee
- Detroit River
- Other shallow aquifers
- Salina A-2 unit
- Salina A-1 unit
- Guelph
- Clinton-Cataract
- Trenton-Black River
- Cambrian

*data in hollow symbols from Shouakar-Stash (2008)*
Sulphate and DIC Isotopes

\[ \delta^{34}\text{SO}_4 \% (\text{CDT}) \]

\[ \delta^{18}\text{O}_4 \% (\text{VSMOW}) \]

\[ \delta^{13}\text{C} \% (\text{VPDB}) \]
Geochemical Tool

Source Composition Database

Mixing Model
(“SIAR” – Parnell et al., 2010)

Unknown Sample Chemistry

Prediction of Fluid Source(s) (+ Proportions)
Model testing

End-members

• Shallow waters split into high and low-δ\(^{18}\)O
  – “Dev-high” > −8‰
  – “Dev-low” < −15‰
• Salina A-1, A-2 and Guelph combined
  – “Salina-Guelph”
• Clinton-Cataract, Trenton-Black River and Cambrian → separate end-members

Demonstration mixtures

• 1 – 50% Dev-low
  50% Dev-high
• 2 – 25% Dev-low
  25% Dev-high
  50% Salina-Guelph

• AWP site: T012111
Mixture 1

50% Dev-low
50% Dev-high
Mixture 2

- 25% Dev-low
- 25% Dev-high
- 50% Salina-Guelph

Source proportions probability densities

Matrix plot
Well T012111
Concluding remarks

- Range of geochemically different groundwaters in SW Ontario
  - $\delta^{18}$O, $\delta^2$H, $^{87}$Sr/$^{86}$Sr, $\delta^{37}$Cl and $\delta^{81}$Br
  - Differences can be exploited to predict the sources of unknown fluids
- SIAR predicts source proportions with good accuracy
  - Potential for substitution between formation may lead to under- or over-prediction of source proportions
    - Good understanding of model is important for interpretation
- Method has already been used to successfully plug one well, and a second is underway
- Significant potential for other applications
Thanks for listening!

Any questions?