Constraining Continental Emergence:
Neoarchean-Paleoproterozoic ocean crust as a record of sea water isotopes

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Motivation:

Continental emergence is poorly constrained. Oxygen isotopes serve as a tracer for ancient seawater. The OISW reflects the balance of two major fluxes: hydrothermal alteration of ocean crust and continental weathering.

Importance of Continental Emergence:

- Influence geologic cycles
- Affects climate change
- Physical habitat space
- Sustains/promotes organic life
- Evolution of multicellular organisms 1.7 Ga

Research Question: What can the record of sea water oxygen isotopes tell us about continental emergence?

If continents are submerged, little subaerial weathering occurs, and the OISW will be relatively enriched in ^{18}O, since weathering sequesters ^{18}O relative to ^{16}O on continents. If the continents are emerged, then the OISW would more closely match the modern value of about 0‰ (VSMOW).

1a.)

DCM2021 050, Spring Mountain

1b.)

DCM2021 017, Tres Lagunes

1c.)

DCM2021 042, Willow Creek

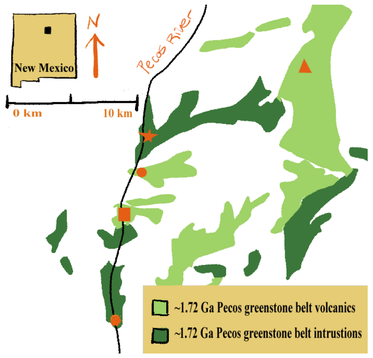


Fig. 1. Geologic map of Pecos, NM. Sites are orange dots; top down: [Spring Mountain, Mora Camp, Willow Creek, Tres Lagunes, Dalton Picnic Area]. Adapted from Slack, 2009. Samples represent all parts of a hydrothermal cell, including recharge and discharge zones.

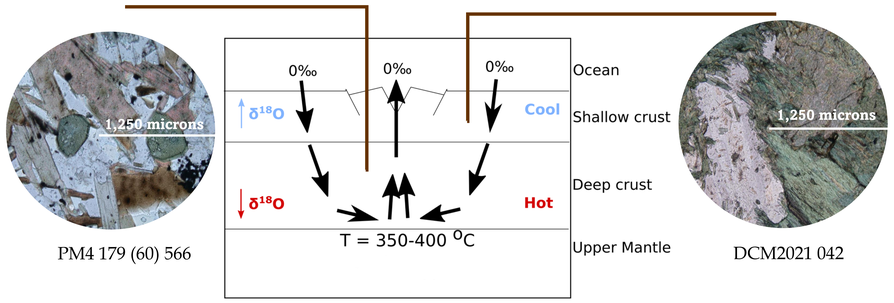
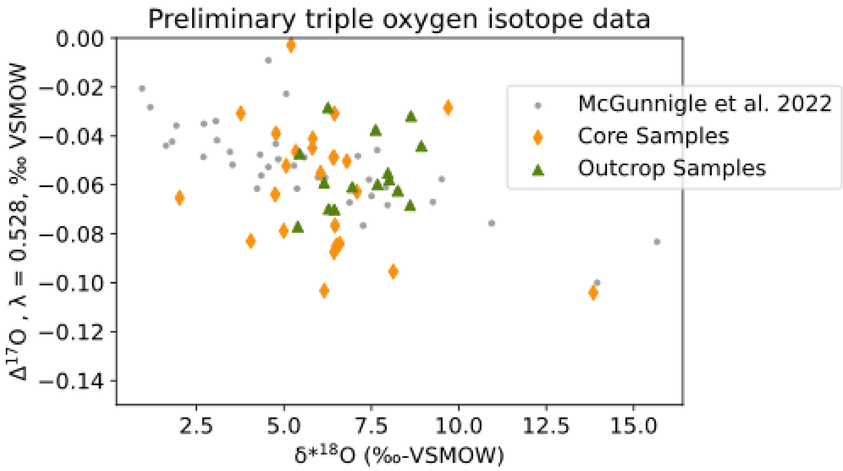


Fig 2. Cross section of a hydrothermal vent system

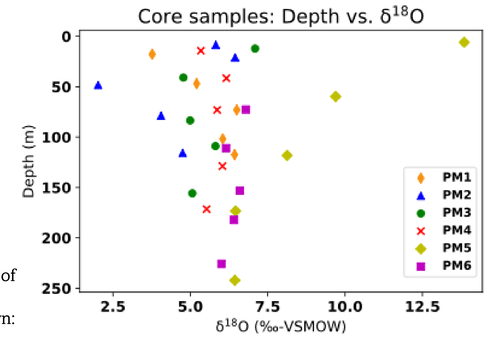
Hydrothermal crust records ancient seawater composition:

- Ocean crust interface in direct contact with homogenous bottom water
- Records broad outcrop scale patterns of alteration
- Interact at relatively high temperatures, harder to reset $\delta^{18}O$ value.

3a.)



3b.)



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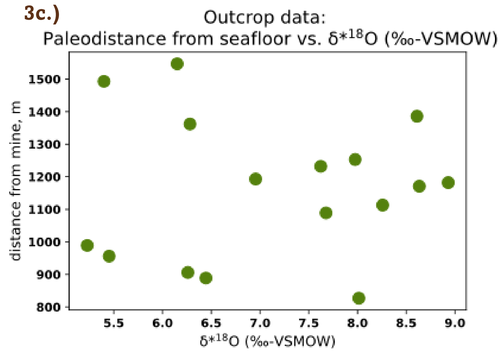
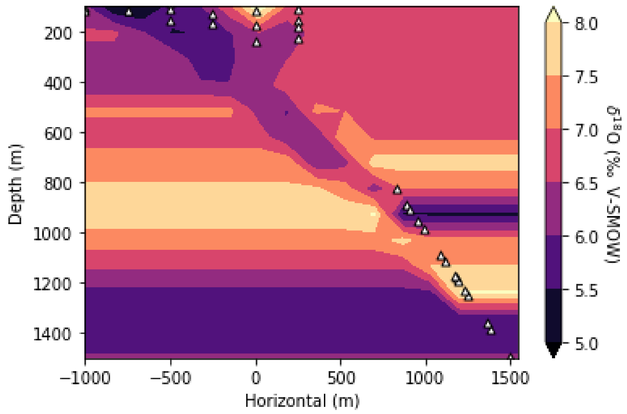


Fig 3. a.) Preliminary triple oxygen isotope data consisting of outcrop samples and core samples, plotted against preexisting literature (McGunngile et al. 2022). Pattern broadly matches with a slightly larger spread in the $\Delta^{17}O$. b.) Core data relationship of depth (m) vs. $\delta^{18}O$. PM5 shows an excellent relationship between $\delta^{18}O$ and increasing depth. c.) Outcrop data demonstrating the relationship between $\delta^{18}O$ vs. the distance from paleoseafloor represented by the Willow Creek mine.



Inverse Model:

Regularly gridded data is processed using tracer-mass balance inverse techniques to estimate the total amount of fluid needed to create alteration patterns. Using total fluid and rock oxygen isotope data, we can constrain the initial water $\delta^{18}O$.

Fig 4. Example of a cross section from Kangaroo Caves, Australia (~3.2 Ga) where irregularly spaced samples have been contoured onto a regular grid.

Results/Discussion:

- Data from Noranda and Sturgeon Lake have $\delta^{18}O$ values that suggest late Archaean to early Proterozoic emergence
- Outcrop samples exhibit slight alteration, mainly chlorite and biotite alteration.
- Core samples exhibit more alteration, more sulfides present.
- Preliminary triple oxygen isotope data different than modern altered ocean crust trend, greater spread in $\Delta^{17}O$.
- Outcrop/Core samples contain high silica, expected from Archean-Neoarchaean oceans.

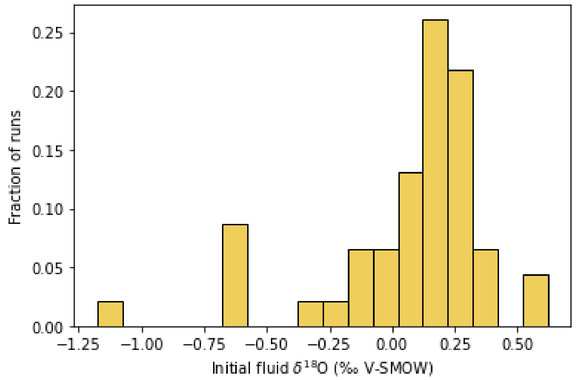


Fig 5. Preliminary results for initial seawater $\delta^{18}O$ value. ~0.03 ± 0.3‰ VSMOW. Average of fraction runs are plotted on Fig 6 for an estimated prediction of continental emergence.

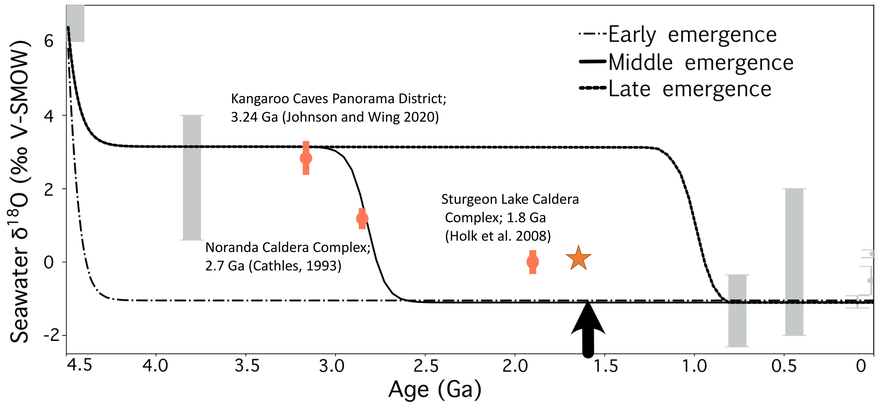


Fig 6. Predicted Model of continental emergence. Grey rectangles represent previous estimates. Orange rectangle represents data from Johnson and Wing 2020 and this study: Kangaroo caves (3.2 Ga), Noranda (2.7 Ga) and Sturgeon Lake (1.8 Ga), Pecos, New Mexico (1.72 Ga).

Johnson, B.W., Wing, B.A. Limited Archaean continental emergence reflected in an early Archaean 18O-enriched ocean. Nat. Geosci. 13, 243–248 (2020). https://doi.org/10.1038/s41561-020-0538-9

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