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Defining the geochemical composition of the newly discovered NEOM Brine Pool and underlying sedimentary pore waters, Gulf of Aqaba, Red Sea

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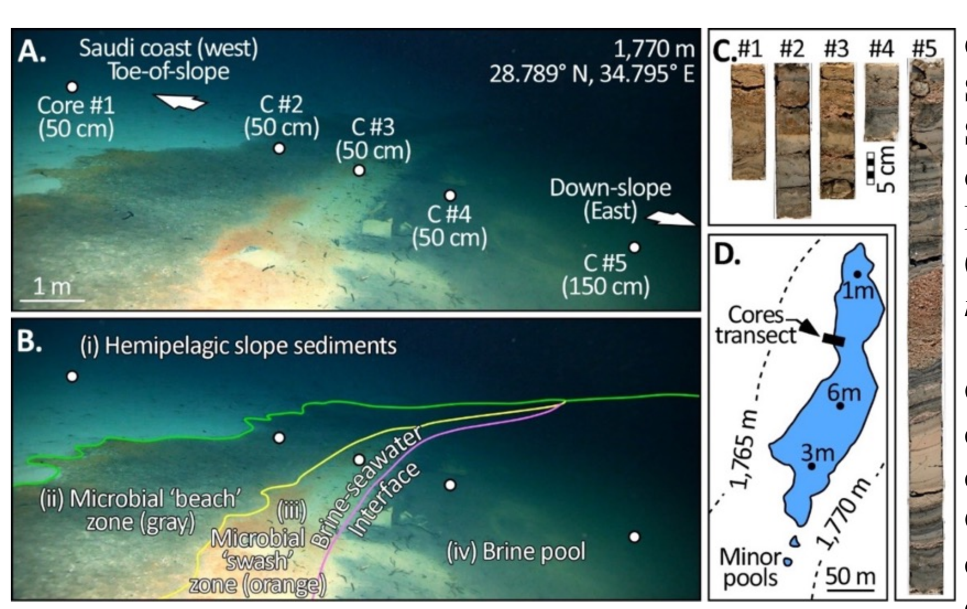
ABSTRACT

Brine pools are dense bodies of highly saline water that accumulate in depositional lows in the seafloor, and they often host rich extremophile microbial communities with metabolisms analogous to those that arose on early Earth. Since the early 1960's, several deep-sea brine pools have been discovered in the Red Sea, and many researchers have worked to classify these pools into conceptual models. The first integrates the brine pool temperature and general depositional setting (Duarte et al., 2020). In this model, brine pools like Discovery and Atlantis II are considered 'hot, axial' brine pools, while brine pools like Afifi and Thuwal Seeps, which are located much closer to the coastlines with lower temperatures, are considered 'cool, coastal brines' (Anschutz et al., 1999; Antunes et al., 2011; Backer & Schoell, 1972; Batang et al., 2012; Cochran et al., 1986; Duarte et al., 2020; Gurvich, 2006). The second conceptual framework aims to classify the brine pools based on the origin of the brines (Schmidt el al., 2015). In this second conceptual model, two types of brines were delineated : Type 1 and Type 2 (Schmidt el al., 2015). The brine chemistry of Type I pools is predominantly controlled by evaporite dissolution and sediment alteration, while Type II brine pools are primarily influenced by hydrothermal activity (Schmidt et al., 2015). In 2020, a first of its kind brine pool was discovered in the Gulf of Aqaba during the NEOM-facilitated OceanX 'Deep Blue' research cruise. The NEOM brine pool is a cold-water, anoxic brine pool that is situated at abyssal depths (1,770m) in close proximity to the coastline, and was the first brine pool discovered outside the Red Sea proper (Purkis et al., *in review*). CTD measurements of *in situ* temperature indicate that the NEOM brine pool (21°C, Purkis et al., *in review*) is not a hot brine pool, suggesting that it is most similar to the Thuwal Seeps and Afifi Brine Pools (Batang et al., 2012; Duarte et al., 2020). During the OceanX cruise, a transect of 5 short sediment cores (50-150cm) were collected across the western edge of the brine pool, radiocarbon dating indicates that the sediments recovered from these cores span the past 1,200 years (Purkis et al., *in review*). Thus, motivated to better understand the geochemical conditions that characterize the NEOM brine pool, we compared measurements of elemental concentration of the brine pool chemistry to interstitial pore waters extracted using Rhizon samplers in each of the 5 sediment cores, and the results from Core 5 located in the center of the brine pool are presented here. These pore water samples were analyzed for elemental composition, alkalinity, and pH. Our results suggest that sediments directly underlying the center of the brine pool (0-10 cm below the sediment-brine pool interface) contain interstitial pore waters that are less saline than the overlying brine. As proposed by Schmidt et al. (2015), cross plots of Mg/Ca ratios and boron concentrations indicate that the NEOM brine pool is chemically most similar to Type 1 pools like Oceanographer and Kebrit, suggesting that a combination of hydrothermal alteration and sediment-water interaction have produced the brines observed in the NEOM pool. Using this new elemental dataset allows for comparison to other brine pools of the Red Sea, as well as an evaluation of potential sources of brines to this anoxic brine complex. Better understanding of chemical conditions in these extreme environments can provide modern insight into the geological past, when life may have evolved in high salinity, anoxic seawater (Antunes, 2017; Macinelli et al., 2004).

MATERIALS & METHODS

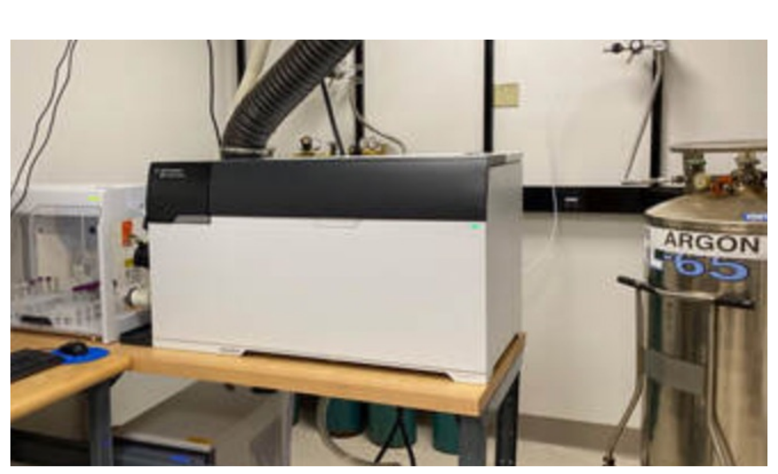


Geological Settings and Sediment Cores of the NEOM Brine Pool (Purkis et al., *in review*)

Cores #1-4: 50-cm sediment cores
Core #5: 150-cm sediment core

Pore water extraction using 5-cm Rhizon samplers

- Samples filtered to 0.22 mm
- 57 pore water samples
- Volumes recovered between 5-15 cm^3



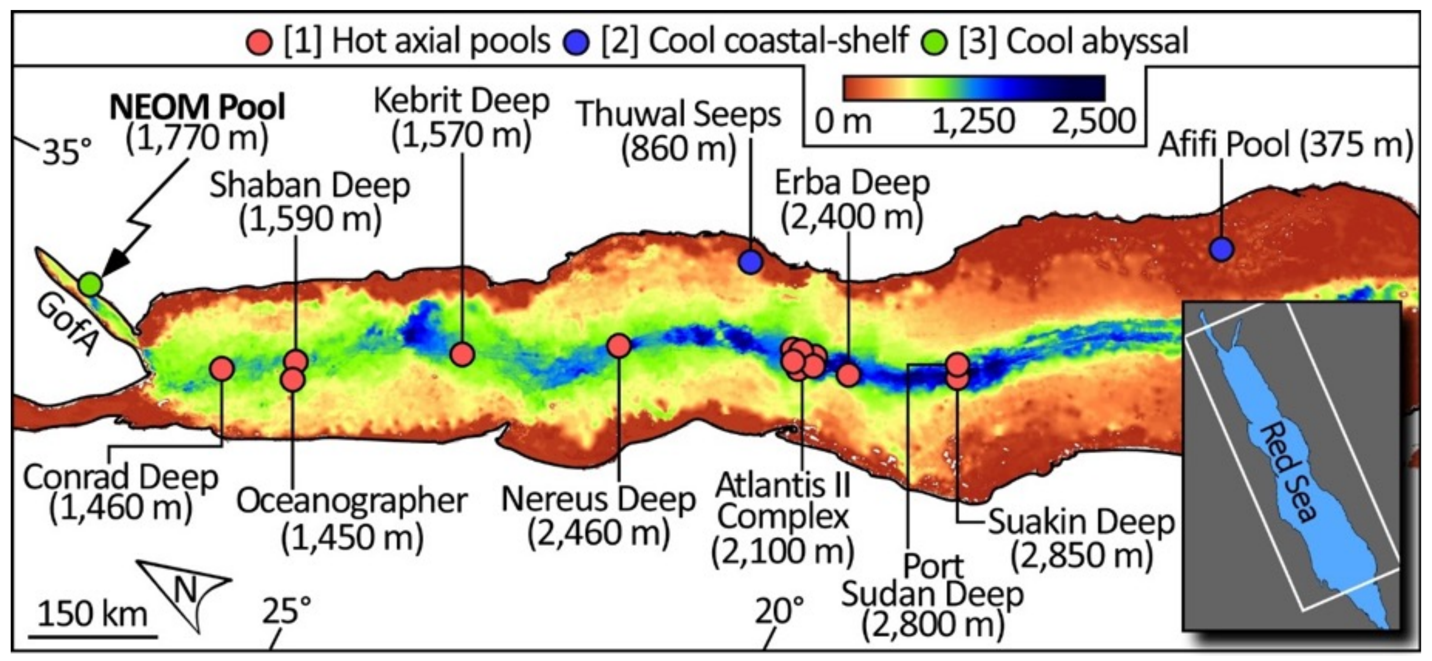
Preparation: Serial dilution with 1% ultra trace nitric acid
Analysis: Samples analyzed in Agilent 8900 QQQ-ICP-MS using MS/MS mode (He, H2, or O2 in the CRC) for analysis of elemental concentrations

CONCEPTUAL MODELS

At least two conceptual models to differentiate the types of brine pools observed in the Red Sea have been developed:

1. *Hot, deep-sea brine pools within the axial trough vs. cool, shallow, shore-proximal pools*
2. *Type I (evaporite dissolution) vs. Type II (hydrothermally influenced)*

Pool	Model 1: Hot-axial and Cool-coastal		Model 2: Type I and II	
	Type	Source	Type	Source
Afifi	Cool coastal	Duarte et al., 2020	----	----
Albatross	Hot axial	Backer & Schoell, 1972	Type II	Schmidt et al., 2015
Atlantis II	Hot axial	Ross & Hunt, 1967; Backer & Schoell, 1972	Type II	Schmidt et al., 2015
Conrad	Hot axial	Cochran et al., 1986	Type II	Schmidt et al., 2015
Discovery	Hot axial	Ross & Hunt, 1967; Backer & Schoell, 1972	Type II	Schmidt et al., 2015
Erba	Hot axial	Backer & Schoell, 1972	Type II	Schmidt et al., 2015
Kebrit	Hot axial	Backer & Schoell, 1972	Type I	Schmidt et al., 2015
Nereus	Hot axial	Anschutz et al., 1999; Backer & Schoell, 1972	Type II	Schmidt et al., 2015
Oceanographer	Hot axial	Backer & Schoell, 1972	Type I	Schmidt et al., 2015
Port Sudan	Hot axial	Anschutz et al., 1999; Backer & Schoell, 1972	Type II	Schmidt et al., 2015
Shaban	Hot axial	Hartmann et al., 1998	Type II	Schmidt et al., 2015
Suakin	Hot axial	Anschutz et al., 1999; Backer & Schoell, 1972	Type II	Schmidt et al., 2015
Thuwal Seeps	Cool coastal	Batang et al., 2012	----	----



Map of the Red Sea, previously studied brine pools, and the new NEOM brine pool (Purkis et al., *in review*)

OBJECTIVE

The purpose of this study is to analyze the geochemistry of the brine pool and porewaters extracted from sediments directly underlying the NEOM Brine Pool. Specifically, Mg/Ca ratios, B concentrations, and brine pool temperature will aid in comparisons between the geochemistry of the NEOM Brine Pool and the other categories of brine complexes in the Red Sea and provide new insight into the chemical processes occurring in this environment and the origin of the brine.

QUESTIONS

- **How does the geochemistry of the NEOM Brine Pool compare to previously studied pools of the Red Sea?**
- **Where does NEOM fit in brine pool conceptual models?**
- **What is the origin of the NEOM Brine Pool?**

RESULTS

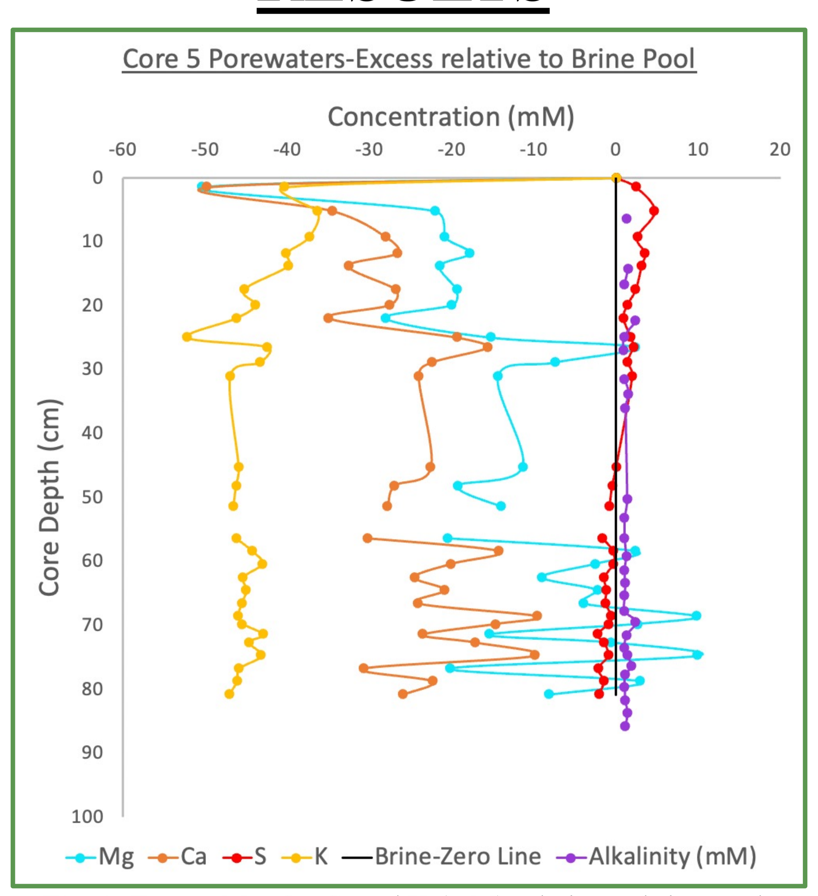


Fig. 1: Excess Mg, Ca, S, and K (mM) relative to brine pool

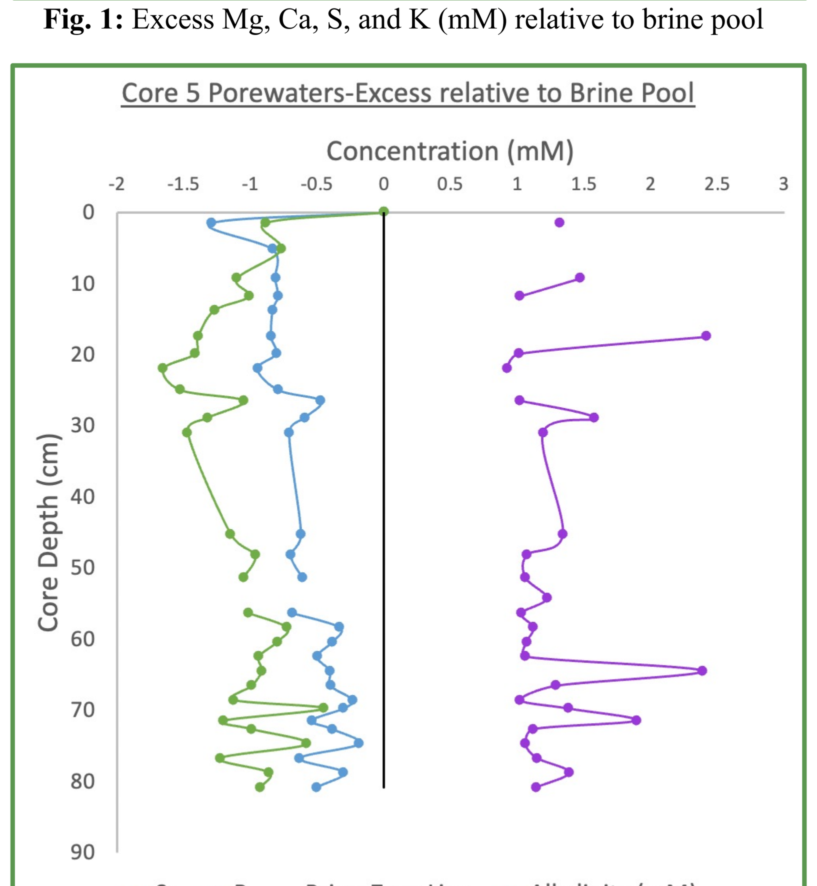


Fig. 2: Excess Sr and B (mM) relative to brine pool

- Significant decrease in [Mg, K, and Ca] at the brine-sediment interface (Fig. 1)
- [S] is higher in the PW of the upper portion of Core 5 than the brine pool until 48.2 cm (Fig. 1)
- [Mg] is generally lower in the PW than in the brine except at 26.5, 58.4, 74.8, and 78.8 cm (Fig. 1)
- Although low overall, there is an increase in excess concentrations of K, Ca, Mg, Sr, B at 26.5 cm (Fig. 1,2)
- B and Sr concentrations are generally lower in the PW than the brine pool (Fig. 2)
- The alkalinity of the PW is generally higher than the brine pool by ~1 mM (Fig. 2)
- Increases in alkalinity, [Mg], and [Ca] ~67-68 cm → potential indicators of carbonate mineral dissolution
- Mg/Ca ratios vs [B] suggest NEOM is the 3[rd] Type 1 brine discovered in the Red Sea region (Fig. 3)
- Core 5 porewaters suggest that brines in the NEOM pool may be mixing with pore fluids influenced by volcanic rock alteration (Fig. 3)

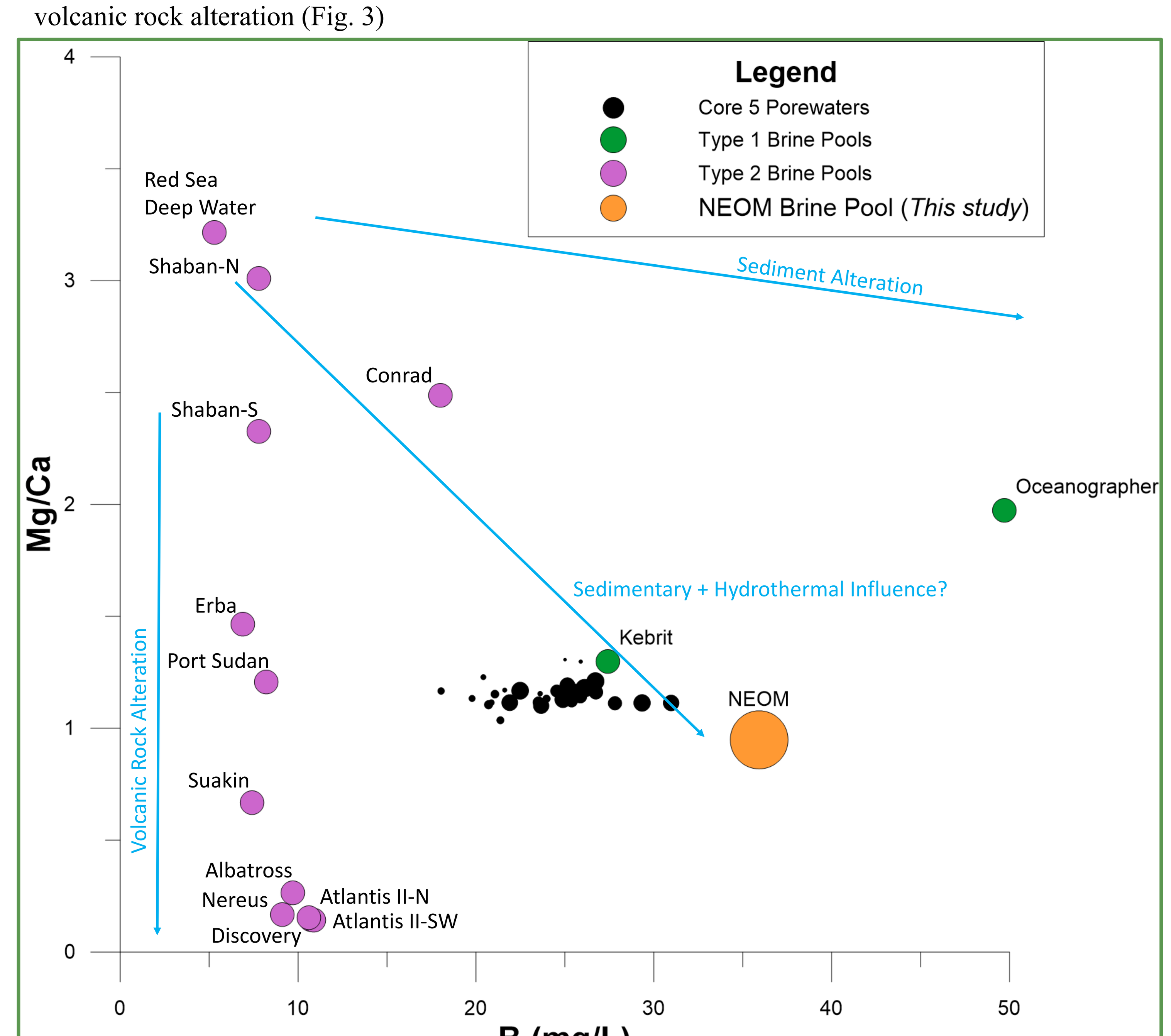
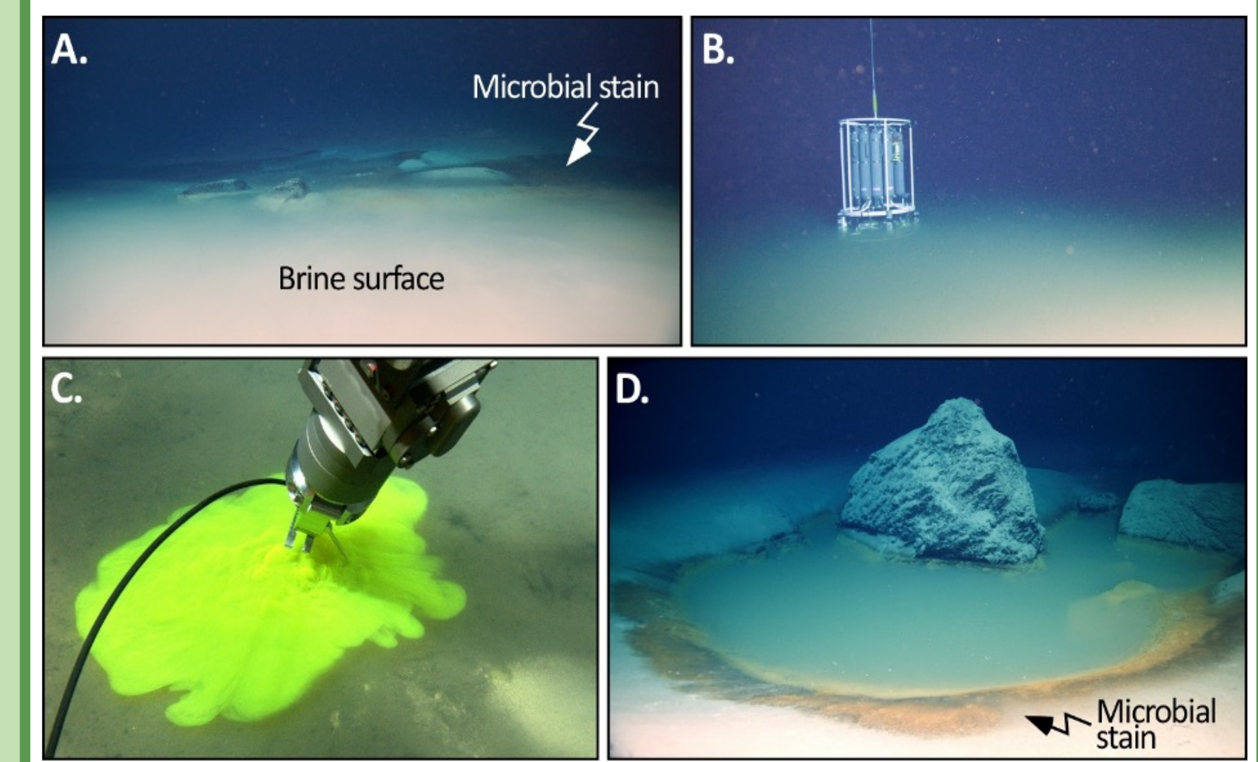


Fig 3: B (mg/l) vs. Mg/Ca adapted from Schmidt et al. (2015) to include the NEOM Brine Pool and Core 5 porewaters. *Note that concentrations are in mg/L in convention with Schmidt et al. (2015) and the size of the Core 5 Porewaters markers reflect core depth (larger markers indicating deeper core depths).

STUDY SITE



Purkis et al., *in review*)

SUMMARY & RECOMMENDATIONS

- **Summary**
  - The elemental composition of the Core 5 porewaters suggest a mixing of 2 different brine sources (Fig. 3)
  - Using the conceptual model for brine pool classifications from Schmidt et al. (2015), the geochemistry of the NEOM Brine Pool is a Type I brine pool
    - This suggests that NEOM is predominantly controlled by evaporite dissolution and contributions from sediment alteration (Fig. 3)
  - Differences in the brine and porewater geochemistry suggest potentially different origins of the NEOM brine pool itself and its underlying sediment porewaters (Figs. 1-3)
- **Future research recommendations:**
  - Integrate with S, O, H isotope values measured by collaborators (Swart, Moore) on porewaters to support interpretation
  - Extract and analyze sedimentary pore waters from other Red Sea brine pools for comparison
  - Re-examine conceptual models and classifications of the Red Sea brine pool types to identify which are best analogues for ancient Earth
  - Consider using an anoxic glovebox when collecting CTD samples or porewaters to maintain the speciation of sulfur in samples from these extreme environments

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