Noble gases in the Ocean – Recent examples from the modern and Paleocean

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Noble gases have made significant contributions to studies of a variety of oceanographic fields. The applications of noble gases, in particular helium isotopes, include the modern oceanic circulation, paleoceanography, hydrothermal systems, deep-sea brines, and ocean/atmosphere gas exchange and cover the time scales from years to Myr.

In order to outline the potential of helium isotopes in the ocean, we present two case studies, one from the field of tracer oceanography and one from paleoceanography.

(i) Tracing modern ocean circulation by mantle helium: Hydrothermal fluids, frequently enriched in ^{3}He by more than one order of magnitude compared to background seawater concentrations and characterized by a typical MORB signature ($\sim 8 \cdot R_a$), are injected at the crest of the Mid-Ocean Ridges at depths of 2000 to 2500 m. Eventually, after more or less complex circulation patterns within the ocean, the ^{3}He injected in this way is lost to the atmosphere via air/sea gas exchange. Between injection at depth and loss at the sea surface, the ^{3}He signatures imprinted by hydrothermal activity can easily be detected in the intermediate depth waters that spread away from the injection points for up to thousands of km. The patterns of the mantle helium plumes observed at intermediate depth in the major ocean basins depend on the strength of the source at the mid ocean ridges, as well as the oceanic circulation. The observed mantle ^{3}He distributions can be used to derive spreading patterns of intermediate waters in the ocean. Examples from the major ocean basins are presented and major differences observed between the individual ocean basins are discussed.

(ii) Extraterrestrial helium and paleoceanography: Paleoceanographic applications of noble gases are based on the fact that ocean sediments accrete extraterrestrial ^{3}He that is delivered to the earth surface by interplanetary dust particles (IDPs). Because ^{3}He is enriched in IDPs by up to 8 orders of magnitude compared to terrigeneous matter, it can be readily detected. If a constant IDP flux is assumed, the ^{3}He distribution in sediments can be used to determine instantaneous sediment accumulation rates. In the paleoceanographic context, constant flux tracers are valuable tools because they enable reconstructions of particle fluxes, i.e. potential climate-sensitive parameters such as oceanic productivity. We present a recent example of a re-evaluation of the connection between ocean productivity and glacial-interglacial cycles based on the CFPs (constant flux proxies) ^{230}Th and ^{3}He. While the currently established CFP ^{230}Th is limited to the last 300 kyr, extraterrestrial ^{3}He holds the potential to extend the time scale to the million year range.

$\Delta^{33}S$, $\delta^{34}S$ and $\delta^{13}C$ constraints on the Paleoproterozoic atmosphere during the earliest Huronian glaciation

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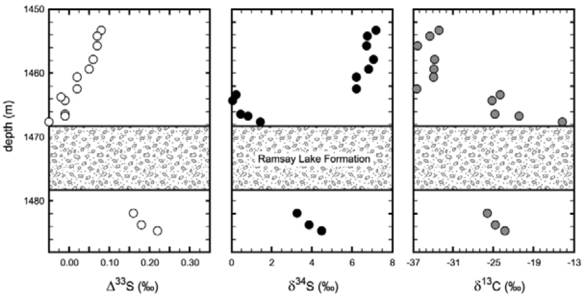
The Huronian Supergroup of southern Ontario, Canada preserves a record of Paleoproterozoic glaciations in a succession of three diamictite-bearing intervals deposited between ~2.4 and ~2.2 Ga. The presence of one or more stratigraphically equivalent glacial diamictites on continents other than North America supports the interpretation that the Huronian glacial intervals represent a global Paleoproterozoic event. We report $\Delta^{33}S$ and $\delta^{34}S$ of Cr-reducible sulfur and $\delta^{13}C$ of total organic carbon from high resolution (average spacing ~2 m) drill-core samples through the earliest glacial interval, represented by the diamictite of the Ramsay Lake Formation, the underlying McKim Formation, and overlying Pecors Formation. Profiles of $\Delta^{33}S$, $\delta^{34}S$, and $\delta^{13}C$ vary



systematically below and above the Ramsay Lake Formation. The variations can be arranged into three distinct groups that occur: (1) from within ~6-3 m of the lower contact of the diamictite; (2) from the upper contact of the diamictite to ~5 m above; and (3) from ~6-15 m above the upper contact of the diamictite. Across these regions, $\Delta^{33}S$ ranges from 0.22 to ~0‰, $\delta^{34}S$ from ~7 to ~0‰, and $\delta^{13}C$ from ~-15 to ~-37‰. The small range of $\Delta^{33}S$ is consistent with the deposition ages of the McKim and Pecors Formations, which fall within the ca. 2.45-2.05 Ga region where the mass-independent record of Earth's early sulfur cycle tapers off (Farquhar et al., 2000). The strong covariation among $\Delta^{33}S$, $\delta^{34}S$, and $\delta^{13}C$ carries significant implications for Paleoproterozoic atmospheric evolution, the coeval global carbon and sulfur cycles, and the initiation and termination of the earliest Huronian glaciation. Our presentation will address these implications in detail.

References

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