Iron isotope evidence for redox stratification of the Archean oceans

K. E. YAMAGUCHI[1, 2, 3], B. L. BEARD[2, 3], C. M. JOHNSON[2, 3], N. OHKOUCHI[1] AND H. OHMOTO[3, 4]

[1]IFREE (Institute for Frontier Research on Earth Evolution), Yokosuka, Kanagawa 237-0061, Japan (kosei@geology.wisc.edu)
[2]Department of Geology & Geophysics, University of Wisconsin – Madison, Madison, WI 53706, USA
[3]NASA Astrobiology Institute
[4]Astrobiology Research Center, The Pennsylvania State University, University Park, PA 16802, USA

Iron isotopes have the potential for tracing Fe geochemical cycling. Inferred redox evolution of the Precambrian atmosphere and oceans at around 2.2 ~ 2.0 Ga (Holland, 1994) should reflect changes in Fe geochemical cycling. In the modern oxic world, chemical weathering, sedimentary transport and diagenesis appear to only play a minor role in producing Fe isotope variations (Beard et al., 2003). Hence, there may be differences in the Fe isotope composition of sediments deposited in a globally anoxic world as compared to an oxic environment.

We measured the bulk-rock Fe isotope compositions of (1) ~3.3 Ga black shales (deeper facies) and graywackes (shallower facies) of the Fig Tree Group (drillcore MRE10 and PU1308), (2) ~2.7 Ga black shales of the Jeerinah (deeper facies, drillcore WRL1) and Lewin (shallower facies, drillcore RHDH2A) Formations of the Fortescue Group, Australia, and (3) for comparison the Cretaceous black shales and adjacent limestones, Italy.

There are differences in the Fe isotope compositions of shallow- and deep-water facies Archean shales/graywackes, where for example, 3.3 Ga graywackes have a δ^{56}Fe of +0.04 ± 0.10 (1σ) ‰ (n = 9); 2.7 Ga shallow-facies black shales have a δ^{56}Fe of +0.07 ± 0.26 ‰ (n = 8), whereas 3.3 Ga black shales have a δ^{56}Fe of -0.07 ± 0.19 ‰ (n = 22) and 2.7 Ga deep-facies black shales have a δ^{56}Fe of -0.86 ± 0.38 ‰ (n = 6). The shallow facies sediments have slightly positive δ^{56}Fe values, whereas the deep-facies sediments have negative δ^{56}Fe values. A similar relationship is found in Cretaceous sedimentary rocks deposited during the Oceanic Anoxic Event (OAE2); -0.10 ± 0.23 ‰ (n = 6) for black shales and +0.08 ± 0.12 ‰ (n = 4) for limestones.

The above observation could be explained by difference in the oceanic δ^{56}Fe signatures that are reflected by sediments and/or differences in the abundance and δ^{56}Fe values of Fe-bearing minerals in sediments. We tentatively interpret the above observations to perhaps reflect, at least locally, the existence of a redox stratification in the Archean oceans, i.e., coexistence of shallow oxic water (~0 ‰ Fe pool) and deep anoxic water (≤ 0 ‰ Fe pool), similar to Cretaceous oceans. Future work is needed to determine whether the anoxic deep water developed locally or globally. Our study has astrobiological implications for the redox evolution of the atmosphere and oceans in terrestrial planets.

Measurements of thermal neutron flux from rocks with fission track method

MATAHIKO YAMAGUCHI[1], TAKAHIRO TAGAMI[1] AND AKIRA KUDO[2]

[1]Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University, Kyoto, Japan (yamaguchi@kueps.kyoto-u.ac.jp)
[2]Research Reactor Institute, Kyoto University, Kyoto, Japan

To measure the in-situ thermal neutron flux from rocks is important in dating groundwater with ^{36}Cl. ^{36}Cl is produced through reactions of ^{35}Cl etc. with thermal neutrons. At depths greater than a few meter, ^{36}Cl is produced through only reactions with thermal neutrons from surrounding rocks because thermal neutrons from cosmic ray don't arrive. Therefore, to measure thermal neutron flux from rocks contribute to estimate of groundwater residence time.

In this research, we used fission track method for measurements of thermal neutron flux. ^{235}U are caused induced fissions by thermal neutrons and consequently fission tracks form in insulating materials. Because the rate of this reaction is in proportion to thermal neutron flux, the flux is able to be estimated with fission track density. Since it was supposed that thermal neutron flux from rocks is small, as many tracks as possible must be formed and the tracks must be observed certainly. So, we used uranium electrodeposits which had many uranium contents and were thin sources. And we used micas as detectors which were insulators because the electrodeposits were not insulators.

As a result, it was possible to observe fission tracks by thermal neutrons from granite whose diameter was about one meter and to estimate thermal neutron flux. On the other hand, it was not possible to observe tracks by thermal neutrons from granite and other rock whose diameter were about 30 centimeter. This is considered that neutrons produced in the rocks couldn't reduce their energy to thermal neutrons because the rocks were small. Therefore, preparing proper conditions is possible to measure thermal neutron flux from rocks with fission track method.