6.6.23

Origin of black carbonaceous cherts in the Barberton greenstone belt

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Early Archaean black carbonaceous cherts in greenstone belts of the Pilbara craton and the Barberton greenstone belt contain the oldest, albeit disputed morphological evidence for life on Earth in the form of microfossils. Carbonaceous cherts occur as sedimentary horizons that are intercalated with komatiitic to basaltic volcanic sequences. A distinct variety of carbonaceous chert forms dykes oriented at high angles to stratification, mostly stratigraphically underneath and in direct contact with a sedimentary chert unit. Most researchers suggest a hydrothermal, black-smoker type origin for the dykes, which are regarded as feeder channels for overlying sedimentary chert horizons. Dykes in the Barberton greenstone belt have also been interpreted as fissures that were filled with biogenic sediment from above.

Detailed field studies combined with trace element geochemistry of a variety of 3.47 to 3.25 Ga chert horizons and chert dykes in the Barberton greenstone belt suggest the operation of different processes at different times for the formation of carbonaceous cherts. As suggested by previous workers, many carbonaceous chert horizons represent sedimentary horizons that were silicified early in their depositional history. Carbonaceous matter may represent primary biogenic material that accumulated together with lithic detritus. However, some carbonaceous chert horizons were silicified (chertified) long after deposition took place. Such horizons consist of silicified sedimentary and volcanic rocks, now black carbonaceous cherts, and are situated adjacent to shear zones that acted as channelways for hydrothermal fluids.

Chert dykes occur as cross-cutting fissures and stratiform veins, and formed part of a subsurface hydrothermal system. Chert veining is mostly attributed to hydraulic fracturing of overpressured hydrothermal fluids beneath early silicified, stratiform chert horizons. These sedimentary horizons acted as impermeable barriers for hydrothermal fluid circulation, as indicated by local ponding of black chert beneath stratiform chert horizons. No evidence for the original communication between the surface environment and the subsurface hydrothermal system has been observed, negating previous models for the origin of chert dykes in the Barberton greenstone belt. It remains unclear if the carbonaceous matter in shear zones and dykes represents biogenic or abiogenic material, but a biogenic origin of the carbonaceous matter would indicate a subsurface habitat of early life.

6.6.31

Iron-sulfur-carbon contents and isotope systematics of 2.7 Ga shallow and deep facies black shales from the Hamersley Basin, Australia

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Systematics of Fe-S-C_{org} (organic C) in sedimentary rocks and sediments have been widely used in deciphering paleoredox sedimentary environments [e.g., 1]. The biogeochemical behaviors of these redox-sensitive elements is likely to have changed after the inferred Great Oxidation Event (GOE) at around 2.2~2.0 Ga [e.g., 2]. In order to characterize the biogeochemical behaviors of Fe, S, and C_{org} prior to the GOE, we have measured the concentrations and isotope compositions of these elements in ~2.7 Ga black shales of the Jeerinah Fm. (drillcore WRL1) and the Lewin Fm. (drillcore RHDH2A) of the Fortescue Group, Western Australia. These shales represent deeper (Jeerinah Fm.) and shallower (Lewin Fm.) facies of a sedimentary basin [e.g., 3].

We have discovered significant differences in the Fe isotope composition between the shales of shallow-facies (δ^{56}Fe = +0.07 ± 0.26 ‰; n = 8) and deep-facies (–0.86 ± 0.38 ‰; n = 6) (Fe isotope compositions are expressed relative to igneous rocks). We have also discovered negative correlations between the δ^{56}Fe values and the Fe^{3+} contents, between the δ^{56}Fe values and the C_{org} contents, between the δ^{56}Fe values and the S contents, between the δ^{56}Fe values and the $\delta^{13}C_{org}$ values, and between the δ^{56}Fe values and the δ^{34}S values. These observations reflect complex biogeochemical cycles of Fe, S, and C_{org} that were mediated by consortia of microbes including cyano-bacteria, sulfate-reducing bacteria (SRB), Fe-reducing bacteria (FeRB), methanogens, and methanotrophs. The deep-facies black shales became: (1) enriched in Fe^{3+} and depleted in ^{56}Fe because of the abundant formation of magnetite by FeRB, and (2) enriched in pyrite contents and varied in the δ^{34}S values because of the high activity of SRB. Our study has implications for the redox evolution of the atmosphere and oceans of the Early Earth.

References

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