

Carbon isotope geochemistry of kerogen in ca. 3.5 Ga hydrothermal silica dikes in the North Pole area, Western Australia

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Abundant organic matter (kerogen) was identified in ~3.5 Ga hydrothermal silica dikes from North Pole area in the Pilbara craton, Western Australia. The field observations suggest that the silica dikes would have deposited from hydrothermal fluid, which circulated in the uppermost 1000 m of the Early Archean oceanic crust. Thus, understanding origin of the kerogen may provide important implications for the origin of life and its earliest evolution.

Petrographic study of 601 specimens of silica dikes together with isotopic (C and N) and elemental (C, N, and H) analyses of the kerogen were performed. The silica dikes are composed mainly of fine-grained silica (modal abundance: ~99%), and are classified into two types by minor mineral assemblages: B(black)- and G(gray)-types. B-type silica dikes contain kerogen (0.37 to 6.72 mgC/g; average 2.44 mgC/g, n=21) and sulfide, which are predominated by pyrite and Fe-poor sphalerite. They sometimes contain carbonate and apatite. Their silica-dominated and sulfide-poor mineral assemblages suggest that the B-type silica dikes were deposited from low-temperature hydrothermal fluid (likely 100-200 C). On the other hand, G-type silica dikes are sulfide-free, and concentrations of kerogen are relatively low (0.05 to 0.41 mgC/g; average 0.17 mgC/g, n=13). They usually contain Fe-oxide (mainly hematite), which often replaced cubic pyrite and rhombic carbonate. Some G-types occur along secondary quartz veins. These textures indicate that the G-type silica dikes were formed by post-depositional metasomatism (oxidation) from the B-types. The metasomatism seems to have been pervasive, but heterogeneous. Thus, sporadically occurred B-types probably possess pre-metasomatic signatures. The $\delta^{13}\text{C}$ values of kerogen in the B-types are -38.1 to -33.1 permil (average -35.9 permil, n=21), which are ~4 permil lower than those of the G-types (-34.5 to -30.0 permil; average -32.2 permil, n=19), and ~6 permil lower than bedded chert (-31.2 to -29.4 permil; average -30.5 permil, n=4). This indicates the preferential loss of ^{12}C during the metasomatism (estimated fractionation factor: 0.9985). Considering diagenetic and metamorphic effects on carbon isotope, we conclude that the original $\delta^{13}\text{C}$ values of the kerogen in the silica dikes would have been -36 +/- 2 permil. The highly ^{13}C -depleted organic compounds were possibly produced by (1) biological carbon fixation, and (2) abiological reaction such as Fischer-Tropsch Type (FTT) synthesis. Although the second possibility can not be eliminated, it is questionable whether the effective catalysts of FTT reaction (e.g., Fe-Ni alloy, magnetite, and hematite) were present in the hydrothermal system. On the other hand, the significant ^{13}C -depletion of the kerogen as well as the physical and chemical conditions of the hydrothermal system are consistent with the biological hypothesis. A remarkable similarity of $\delta^{13}\text{C}$ values between the kerogen and modern hydrothermal vent organisms may suggest that the kerogen was derived from chemoautotrophic organisms. This idea is also consistent with their nitrogen isotopic compositions ($\delta^{15}\text{N}$ = -4.1 to +4.0 permil; average -0.6 permil, n=6). Therefore, it is plausible that the sub-seafloor hydrothermal system was probable habitat of life in the Early Archean.