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The origin of carbonaceous material in the Early Archean Nain Complex, northern Labrador, Canada

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Presence of early life in the Early Archean is still controversial, and it is a key issue to find evidence for early life from the Early Archean rocks. Carbon isotope ratio ($\delta^{13}C_{org}$) of carbonaceous matter (CM) is widely used as an indicator of existence of life (Schidlowski, 2001). CM in the 3.80 Ga metasediments of the Isua Supracrustal Belt (ISB), southern West Greenland has low $\delta^{13}C$ values, interpreted as evidence for organism in the Early Archean (Rosing, 1999). Recently, Ohtomo et al (2013) showed the nano-scale microstructure of the CM, evident for originating from organisms. In contrast, it is presumed that CM in the Nuvvuagittuq Supracrustal Belt (˜3.75Ga) has a secondary metamorphic origin because the crystallization temperature (˜380 ℃) of the CM estimated from LA-Raman spectrums is much lower than than metamorphic temperature (˜640 ℃) (Papineau et al., 2011). Moreover, a putative banded iron formation in the Akilia Island (˜3.83 Ga) including apatites with carbonaceous inclusions with the low $\delta^{13}C$ provides another evidence for the life, but the precursor is still controversial (Fedo and Whitehouse, 2002). Thus, there is no obvious evidence for presence of life in the Early Archean except for that from ISB.

Shimojo et al. (2013) showed that >3.96Ga metasediments exist in the Nain Complex, northern Labrador, Canada. The Nain Complex is *ca*. 100 million years older than the Akilia association, which has the oldest supracrustal rocks in the world. The purpose of this research is to reveal the origin of the CM in the sedimentary rocks in the Nain Complex.

We selected pelitic gneisses (n=70), conglomerates (n=14), carbonate rocks (n=39), cherts (n=30), chert nodules in carbonate rocks (n=3) and amphibolites (n=5) from over 2000 samples over the Nain Complex based on the metamorphic grade, geography, their field occurrence and degree of alteration. Among the metasedimentary rocks (n=156), 54 specimens including pelitic gneisses (n=21), conglomerates (n=4), carbonate rocks (n=26) and chert nodules in carbonate rocks (n=3) contain CM. Seven CM-bearing rock samples were selected for $\delta^{13}C_{org}$ analysis: pelitic gneisses (n=4), conglomerates (n=1), carbonate rocks (n=1) and chert nodules (n=1), and 3 carbonate rock samples for $\delta^{13}C_{carb}$ analysis, respectively.

Metamorphic grade was estimated for mineral paragenesis and garnet-biotite thermometry. Among the seven CM-bearing rock samples, the six samples were metamorphosed under up to the amphibolite facies condition, and a sample under the lower granulite facies condition, respectively. The metamorphic temperatures are consistent with the estimated crystallization temperature of the CM calculated by Raman spectral parameters.

$\delta^{13}C_{carb}$ values range from -3.75 to -2.63 ‰. Because it is well known that secondary alteration and metamorphism decrease a $\delta^{13}C_{carb}$ value (Schidlowski et al., 1979), a primary $\delta^{13}C_{carb}$ value was estimated to be higher than -2.63 ‰. As a result, the $\delta^{13}C_{carb}$ value of marine bicarbonate was at least -2.63 ‰ in the Early Archean.

$\delta^{13}C_{org}$ values of pelitic gneisses range from -28.86 to -14.07 ‰. The $\delta^{13}C_{org}$ values of conglomerate, carbonate rock and chert nodule are -17.52, -5.72 and -10.60 ‰, respectively. Metamorphism, generally speaking, increases a $\delta^{13}C_{org}$ value of CM due to partial thermal decomposition, especially methane degassing, suggesting that the variation in the $\delta^{13}C_{org}$ values is due to secondary thermal decomposition. The correlation of the $\delta^{13}C_{org}$ values with distribution of organic matter under microscopic observation also supports the partial decomposition and consequent increase of the $\delta^{13}C_{carb}$ values. As a result, the lowest δ13Corg value is a maximum estimate of the $\delta^{13}C_{org}$ value.

The minimum fractionation between the $\delta^{13}C_{org}$ and $\delta^{13}C_{carb}$ reaches 25 ‰, indicating biologic origin for the CM. This work presents the organism has already existed *ca.* 3.96 Ga.

Keywords: CM, Labrador, early life, carbon isotopic ratio