The lateral change of Archean hydrothermal system; The Dixon Island Formation in the coastal Pilbara terrane, Australia

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The 3.2 Ga Dixon Island Formation in the coastal Pilbara terrane, Western Australia, is one of the most complete and best-preserved examples of Mesoarchean sequence representing submarine hydrothermal system. Along the northern coastline of the Dixon Island, where continuous sections are well exposed, we conducted detailed geological mapping and sampling. The outcrop (˜3.5 km^2) was subdivided into six blocks, namely DX-A to DX-F (west to east), that were defined by dextral strike-slip faults. The 400m-thick Dixon Island Formation is composed of, in ascending order, Komatiite-Rhyolite Tuff Member (KRTM), Black Chert Member (BCM), and Varicolored Chert Member. Veins of black chert typically contain about 0.3 mm wide carbon rich particlesin KRTM; however, those features diminish in the overlying BCM.

In order to extract characteristic information, recorded in black chert, on the depositional environments influenced by submarine hydrothermal activity and on the potential biological activity, we performed petrographic observations of thin sections under microscope and geochemical analyses of organic carbon (Corg) contents, Corg isotope compositions, and rare earth elements (REEs) abundance of cherty rocks in BCM and black chert veins in KRTM. The number of samples used for analyses is 506.

Lower part of BCM is chiefly composed of 50 to 100cm-thick massive black chert layers which contain carbonaceous particles of ˜0.3mm in diameter. Textures of carbonaceous matter are quite similar to those of black chert veins in KRTM. Middle to upper parts of the BCM contain very finely laminated black chert (alternating layers of carbonaceous matter and chert), red chert (containing very fine grains of Fe-oxide minerals), and dark greenish siliceous shale (containing altered clay material such as white mica).

Geochemical and isotopic characteristics of these rock types show systematic differences. The Corg isotopic compositions are quite different between the massive black chert in the lower/upper BCM (-25 to -30 o/oo) and the laminated black chert in the middle BCM (-30 to -35 o/oo). The latter sometimes exhibits very low Corg isotopic compositions reaching -45 o/oo. The shale-normalized REE+Y patterns of both massive and laminated chert similarly show overall enrichment of heavy REE and positive Eu anomaly, while Y/Ho ratios are higher in the latter than those in the former. The Corg contents of the BCM are generally very low (˜0.5 wt.%); however, those of massive black chert in the BCM decrease laterally (geographically) from 0.18 wt.% in DX-B to 0.02 wt.% in DX-F. Moreover, their Corg isotopic compositions values show somewhat different ranges; -28 to -40 o/oo (DX-B), -27 to -35 o/oo (DX-C), -20 to -35 o/oo (DX-E), and -22 to -33 o/oo (DX-F), respectively. Such differences in the Corg isotopic compositions also exist among black (-30 o/oo), red (-28 o/oo), and green (-26 o/oo) chert in the middle to upper parts of the BCM.

We suggest that, together with petrographic observation, the geographic and lithology-dependent differences in the contents and isotopic compositions of Corg and REE characteristics of the Dixon Island Formation may reflect laterally diverse and complex microbial ecosystem developed in the Archean ocean.