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Earliest life on Earth

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The banded iron formation at Isua in southern West Greenland with an age of 3.8 billion years is one of the oldest known sedimentary rocks and contains potential information about the earliest life on Earth. In these rocks time, temperature and pressure have led to the complete obliteration of any microfossil shapes by destruction or recrystallization of the biomaterials, including carbon to graphite [1]. On the basis of carbon isotope fractionation and structural studies it has been suggested that this graphite is of biogenic origin [2,3]. Graphite also occurs abundantly in nature in forms of inorganic origin from crustal fluids [4] and also from disproportionation of divalent transition metal-, mainly iron carbonates. Such deposits may be confused with the graphite produced by decomposition of organic matter unless physical criteria can be found that distinguish between these genetically different types. Graphite crystallizes in two modifications one metastable with rhombohedral layer stacking the other being the stable hexagonal end member. We found that the graphite in these oldest rocks, have a high proportion of rhombohedral graphite [5]. A caveat for a generalized interpretation of rhombohedral graphite as an indicator of origin from organic matter and therefore of life comes from the observation that hexagonal graphite may convert to the rhombohedral form when exposed to extreme pressure and stress [6,7,8]. The seemingly undistorted microlamination [2] in the Isua carbonaceous shale does not give any clear indication of such deformation but independent signs of subtle metamorphic effects must be sought before final conclusions can be drawn about the evidence from carbon crystal structure alone. We have recently found that the disordered graphite nanocrystals from an early stage of graphitization of clearly biogenic deposits consistently have assumed the rhombohedral structure. This may suggest but does not prove that the rhombohedral carbon in the oldest rocks is biogenic - further evidence is needed to distinguish between rhombohedral graphite formed by decay of organic matter and the same form produced by tectonic metamorphism. A possibility for such a distinction is offered by the fact that the initially formed graphite from organic matter is associated with and partly structurally combined with the decay products of the organic parent material, including species of hydrogen, nitrogen, oxygen and sulfur [9,10]. We postulate that these structural substituents give the initial stabilization to the biogenic rhombohedral graphite and that their gradual loss mediates the progressive hexagonal graphitization. If proven, presence of residual organogenic substituents in the enigmatic oldest rhombohedral graphite could potentially provide the discriminatory evidence.

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