Fluid deposited carbon and biosignatures in Earth's oldest rocks

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Some of the oldest traces of life on Earth have been proposed to be represented as particles of graphitic carbon associated with apatite in meta-sediments older than 3,800 Ma (1). We descibe the occurrence of disordered and crystalline graphitic carbons with apatite in a variety of banded iron formations ranging in age from 4,280 to 2,270 Ma and metamorphic grades from lower greenshcist to granulite facies. Petrographic and associated Raman images show apatite, carbonate and graphitic carbon co-oocuring in veins, pockets and grain boundaries with retrograde and hydrated mineral phases. Additionally, CO_2+CH_4+H_2O bearing fluid inclusions occur as trails along with apatite crystals and carbonate with sulphides. The precipitation of graphitic carbon in the banded iron formations studied, likely occurred due to cooling and dehydration reactions as evidenced by its association with hydrated retrograde phases. Thus we conclude that the precipitation of apatite and Fe-OH silicates led to the removal of OH promoting graphite precipitation. Our observations show apatite-graphite occurences previously proposed as biosignatures for early life (1) are post-depostional and fluid-deposited and not always primary mineralogical associations (2). However, this carbon is derived from primary organic matter present in the depositional environment. Evidence for this is seen as crystalline graphitic carbon co-occuring within only a few micrometres of disordered graphitic carbon. In this scenario, crystalline graphite represents primary organic matter metamorphosed to graphite, whereas disordered graphitic carbon represents devolatilised primary organic matter and precipitation close to the source. The isotopically light signature of these graphitic carbons gives possible origins including biologically or abiotically synthesised carbon.

(1) S. J. Mojzsis *et al.*, *Nature* **384**, 55-59 (1996).
(2) D. Papineau *et al., Nat. Geosci.* **4,** 376-379 (2011).