Graphitic carbons and biosignatures

DOMINIC PAPINEAU[1] AND SYLVAIN BERNARD[2]

[1]London Centre for Nanotechnology and Department of Earth Sciences, University College London, 17-19 Gordon Street, London, United Kingdom.
[2]IMPMC, UMR CNRS 7590, Sorbonne Universités, MNHN, UPMC, IRD UMR 206, Paris, France

Direct investigations of the earliest life and carbon cycle are extremely challenging as biosignatures are inevitably degraded during geological history. Additional difficulties include abiotic pathways, contamination during sample preparation, and fluid alterations during metamorphic history. This contribution reviews recent controversies over Archean and Hadean samples. The goal is to emphasize the critical role that new micro-analytical approaches have in complementing and challenging previous observations.

Possible evidence of life has been reported in ca. 3.83 Ga Akilia Quartz-pyroxene rocks (Greenland) as ^{13}C-depleted graphite inclusions within apatite grains [1]. Three-dimensional Raman imaging and additional *in situ* carbon isotope analyses confirmed these early results [2]. However, foils of such targets micro-fabricated by Focused Ion Beam (FIB) reveal that this graphite rather occurs as coatings on apatite grains [3]. Carbon isotopes independently measured with other techniques also show ^{13}C-depletions, but not as fractionated as those reported earlier [4]. Furthermore, in the ca. 3.75 Ga Nuvvuaguttuq banded iron formation (Canada), there is evidence for late fluid-deposition of graphitic carbon coating on apatite grains [5].

Another recent controversial example is the report of ^{13}C-depleted diamonds and graphitic carbons included in Hadean zircons from the Jack Hills, Australia [6]. FIB foils however show that these graphite-diamond mixtures are mixed with epoxy, leading to the conclusion that they are contaminants from polishing compounds during sample preparation [7]. Similar misleading observations of contaminants have also been noticed in olivine inclusions from a thin section of a peridotite.

Altogether, these and other recent controversies demonstrate that careful sample preparation protocols, an unbiased consideration of the data, and the use of novel micro-analytical techniques are necessary for the search for the earliest traces of life and carbon cycling.

[1] Mojzsis *et al* (1996) *Nature* [2] McKeegan *et al* (2006) *Geology* [3] Papineau *et al* (2010a) *GCA* [4] Papineau *et al* (2010b) *GCA* [5] Papineau *et al* (2011) *Nature Geoscience*; [6] Menneken *et al* (2007) Nature [7] Dobrzhinetskaya *et al* (2014) *EPSL*.