Palaeobiology

# Dating earliest life

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**Claims that 3.8-billion-year-old rocks from Greenland contain carbonaceous remnants of very early life have been the subject of argument for several years. The latest analyses look like settling matters.**

How, where and when did life start? Geologists are helping to address these questions by diligently searching the oldest-known sedimentary rocks on Earth for traces of primitive life, either in the form of cellular microfossils, or as chemical and isotopic tracers characteristic of biological processes.

Since 1996, attention has focused on a small outcrop of supposedly sedimentary rocks, claimed to be more than 3.85 billion years old, on the tiny island of Akilia, just off the west coast of Greenland. These rocks have been too strongly recrystallized in subsequent geological eras by heat and pressure (metamorphism), penetration of deep crustal fluids (metasomatism) and tectonic deformation to preserve fossils. Hence, claims for life there had to be based on the carbon isotope composition of tiny inclusions of graphite (carbon) in grains of apatite (calcium phosphate). Writing in *Geology*, Lepland *et al.*[1] now report that they cannot substantiate claims for the presence of graphite in any of the crucial Akilia apatite grains.

The story began with the publication of two papers[2,3] claiming that $^{13}C$ isotope depletion (that is, low $^{13}C/^{12}C$ ratios) in Akilia graphite supported a biological origin. The host rocks were identified as a banded iron formation (BIF), a chemically precipitated marine sediment normally consisting of alternating bands of iron oxide (magnetite or haematite) and silica (quartz) that might, in principle, harbour remnants of early life. Such rocks are difficult to date directly, but an age of 3.85 billion years or more was claimed from uranium–lead dating of zircon (zirconium silicate) grains in a granitic vein cross-cutting — and therefore younger than — the rock that hosted the BIF. This date provided ammunition for the widespread popular claim that life on Earth began around 4 billion years ago. It also implied that earliest life coexisted with devastating global meteorite impacts, known as the Late Heavy Bombardment, which shaped the Moon's surface and, most likely, that of the Earth until about 3.85 billion years ago.

Following the appearance of the two papers[2,3], scientific debate commenced in earnest. I myself visited Akilia twice, in company with several participants in the unfolding controversy, but I could not understand why these banded rocks had been identified as BIF. Instead of iron oxide, the dark bands consisted of pyroxene (an alumino-silicate of calcium, magnesium and iron) and resembled igneous rocks from very close by. Genuine BIF occurs in quantity some 150 km to the northeast in the famous Isua region, where the best-preserved 3.7–3.8-billion-year-old rocks on Earth occur. The Akilia rocks looked nothing like the Isua BIFs. Detailed chemical and mineralogical evidence soon convinced Fedo and Whitehouse[4] that the rocks were not sediments but strongly metamorphosed, metasomatized and deformed igneous rocks, and thus irrelevant for biology.

The zircon uranium–lead date of 3.85 billion years or older for the Akilia rocks was also questioned, because individual zircon grains are complex, possessing zones of quite different ages within a single grain that represent its long and complex crystallization history. The oldest zones indeed gave nearly 3.85 billion years, but this could be an 'inherited' age, older than the age of the host granitic vein, which some claimed to be no more than 3.65 billion years[5]. Other workers[6] then objected that the granitic vein was not cross-cutting at all, but structurally concordant with its adjacent rock. That meant that the measured age of the granitic vein was irrelevant to the crucial Akilia rock, because any previous field relationship between the two had been obliterated by tectonic forces.

Even more worrying was the proposal[7] that graphite inclusions in apatite grains resulted from thermal dissociation (at temperatures of about 450 °C) of iron-rich carbonates in the rock to iron oxide, carbon dioxide and elemental carbon, the latter with a $^{13}C/^{12}C$ ratio overlapping values indicative of a biogenic origin. This mechanism was suggested to counter claims for supposedly biogenic carbon in the genuine BIFs from Isua[8], which often contain iron-rich carbonate. In fact, only one locality now remains in the Isua region where association of graphite with sedimentary rocks leaves the possibility of a biogenic interpretation open[9]. Exchanges between 'pro-life' and 'anti-life' factions on Akilia have now been published for eight years. However, for many observers the ancient Akilia rocks have gradually appeared as less and less plausible domiciles for biogenic tracers.

Lepland *et al.*[1] investigated many thin sections of Akilia rocks containing apatite crystals by optical and scanning electron microscopy, combined with energy-dispersive spectrometry. This work failed to reveal any graphite inclusions in apatite crystals from the problematic banded rocks or surrounding rocks. Even the most widely discussed sample (known as G91-26), used in the original study[2], proved free of graphite.

This persuasive discovery seems an almost inevitable, yet highly problematic, consequence to the increasing scientific doubts about the original claim. We may well ask what exactly was the material originally analysed and reported? What was the apatite grain with supposed graphite inclusions that figured on the covers of learned and popular journals soon after the discovery? These questions must surely be answered and, if necessary, lessons learned for the more effective checking and duplication of spectacular scientific claims from the outset.

To my regret, the ancient Greenland rocks have not yet produced any compelling evidence for the existence of life by 3.8 billion years ago. The reader is reminded that another debate on early life is currently in progress on 3.5-billion-year-old rocks in Western Australia, where chains of cell-like structures, long identified as genuine fossils[10], have recently been downgraded by some workers[11] to the status of artefacts produced by entirely non-biological processes. To have a chance of success, it seems that the search for remnants of earliest life must be carried out on sedimentary rocks that are as old, unmetamorphosed, unmetasomatized and undeformed as possible. That remains easier said than done. For the time being, the many claims for life in the first 2.0–2.5 billion years of Earth's history are once again being vigorously debated: true consensus for life's existence seems to be reached only with the bacterial fossils of the 1.9-billion-year-old Gunflint Formation of Ontario[12]. ■

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