Journal of Conference Abstracts
Volume 5(2), 491

Origin and Significance of ca. 3.85 Ga Zircons from West Greenland

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The oldest known sediment (Nutman et al., 1997), and the oldest known rock with evidence of biological processes active during time of deposition (Mojzsis et al., 1996), is a ~3-m-thick layer of BIF/quartzite within a body of amphibolite on Akilia island, southern West Greenland. Orthogneisses that crosscut an amphibolite enclave containing BIF/quartzite yield U-Pb zircon ages as old as ca. 3.85 Ga. This is interpreted as the age of crystallization of the magmatic protolith by Nutman et al. (1997). Carbon isotopic evidence of bio-organic activity during deposition of the BIF/quartzite sediments (Mojzsis et al., 1996) would then suggest that the emergence of life on this planet occurred before 3.85 Ga.

Several of the Akilia orthogneisses that cut the BIF/quartzite generally contain three zircon age groupings: ca. 3.85 Ga, 3.65 Ga, and 2.7 Ga. One possible explanation for this is that the ~2.7 Ga grains are metamorphic, the ~3.65 Ga grains are igneous, and the oldest grains are xenocrysts inherited from an older rock. In this latter interpretation, the actual intrusive age of the tonalitic protolith of the gneiss would be only 3.65 Ga. For example, Kamber and Moorbath (1998) and Whitehouse et al. (1999) have argued that the ca. 3.85 Ga ages were assimilated at ca. 750ºC from adjacent, zircon bearing rocks. Yet, there is no identified candidate rock for the assimilant in the whole of West Greenland. The granitoid protolith of the orthogneisses is characterized by relatively low Zr contents (~120 ppm) and high crystallization temperatures (>900ºC). The likelihood of strongly zircon undersaturated tonalitic-granodioritic melts (Harrison and Watson, 1983) intruding into zircon-poor rocks and preserving widespread inherited zircon is low. Kamber and Moorbath (1998) argue that the lack of 3.85 Ga Pb-Pb ages in feldspars from gneisses collected throughout southern West Greenland specifically preclude a 3.85 Ga protolith age for any rocks in West Greenland. However, their conclusion overstates the clarity of interpretations that can be drawn from Pb isotopes in feldspars. Peak metamorphism experienced by these rocks at 3.65 Ga occurred under conditions permitting exchange of primitive Pb isotopes in feldspar with radiogenic Pb released from U-rich phases. McGregor (2000) has pointed out that the petrologically unrelated samples analyzed by Kamber and Moorbath (1998) are actually dominated by relatively late phases of the gneiss complex. These rocks experienced partial melting under granulite facies metamorphism, and thus "do not preclude the existence of very old (>3800 Ma) rocks" on Akilia Island.

Our sample comes from the northern exposure of an orthogneiss sheet that cross-cuts the Akilia amphibolite+BIF/quartzite enclave containing evidence for early life. This sample is from the same locality described in Nutman et al. (1997) for which an age of 3.85 Ga was obtained. Abundant clear, prismatic zircon grains with no obvious evidence for later zircon growth were extracted. We performed U-Th-Pb ion probe geochronological measurements on polished grain Gr/97/16/69 and identified it as being >3.85 Ga in age and concordant. The grain was later removed and remounted, unpolished, with the standard zircon (AS-3). We undertook a depth-profile study of Gr/97/16/69 to obtain information at the sub-micrometer spatial scale about its petrologic environment during initial igneous crystallization, and subsequent episodes of metamorphism. If this zircon was inherited at 3.65 Ga when the tonalite was a melt, as claimed by Moorbath and co-workers (Kamber and Moorbath, 1998; Whitehouse et al., 1999), then we would expect the features of that melt environment to be preserved in the zircon. Our 15 mm depth-profile within zircon Gr/97/16/69 revealed three age zones correlative with the results of Nutman et al. (1997). To test whether this zircon could have been inherited from a pre-existing rock at 3.65 Ga, we compared its Th/U and time-integrated Th/U ($^{208}Pb/^{206}Pb$) depth-profile compositions. The tonalite from which the zircon is derived (now a homogenous grey gneiss) has a typical granitoid Th/U value of 3.8. Zircon grown from a melt with this Th/U composition is expected to have a Th/U ratio of ~0.8. The only age component of zircon Gr/97/16/69 that agrees with this expectation is the 3.85 Ga center, which is identical to the predicted Th/U ratio. In dramatic contrast to this result, the zones at 3.6 Ga and 2.7 Ga are indistinguishable, and could only be recording metamorphic zircon overgrowths beginning at ca. 3.65 Ga. We interpret this as incontrovertible evidence indicating that the only truly magmatic component of these zircons is the in the oldest ages ca. 3.85 Ga. Although prior conclusions of ancient zircon inheritance (Kamber and Moorbath, 1998) are no longer tenable, our interests go to further addressing the structural relations between the ancient BIF/quartzite + amphibolite enclaves and their orthogneiss hosts in West Greenland in the quest for determining the timing of the emergence of the biosphere.

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