LETTER

Questioning the biogenicity of titanite mineral trace fossils in Archean pillow lavas

Staudigel et al. (1) compare early Archean titanite microtextures to recent microtubules in Cenozoic volcanic seafloor glass to support a biogenic origin. However, given the 3.5 billion years of Earth history since eruption of the Archean lavas, many geological processes have affected these rocks, complicating the simple case for trace fossils. Using hollow and partially mineralized microtextures in modern seafloor basalt as an analog for argued microbial alteration of Archean glass is, in our opinion, a weak line of argument and an overextrapolated interpretation in support of biogenicity. The many assumptions required in their proposed bioalteration model are not supported by microbiological experiments or geological observations. For example, Staudigel et al. (1) require that hollow microbial tunnels are filled in by some process forming titanite, but when and how this occurs is not substantiated. The authors also contradict earlier work by abandoning organic carbon linings to the microtextures as evidence in support of biogenicity. Staudigel et al. provide no new data to support a biogenic origin, and we highlight that they have further complicated their lines of argument.

In our article (2), we indicated that Staudigel and his colleagues (1, 3) failed to document the geological and metamorphic context of their candidate trace fossils, including a major approximately 2.9-Ga mafic intrusion directly adjacent to their sample site. Extensive petrographic studies show that the pillow lavas were thermally affected by the intrusion, producing titanite microtextures of various morphologies (2), unlike the fine titanite dustings observed in pillow lavas regionally (4). In their images, all taken from earlier publications, Staudigel et al. (1) confuse hornfelsic titanite formed during thermal metamorphism for apparent igneous "varioles" of undescribed mineralogy. The authors refer to "delicate" textures in limited samples from an approximately 15-m section and make titanite width arguments based on this highly biased sample set, while also adding caveats to the size distribution of recent microtubules used for comparison. Rather, we provide statistical analysis of all titanite microtexture size and shape variation from across the 183-m drill core section spanning the intrusion and the original sampling site of refs. 1 and 3 to propose a metamorphic origin.

No new data are provided by Staudigel et al. (1) to support their suggestion that preexisting titanite was reset at 2.9 Ga; neither do they provide criteria that separate their proposed "signature" microtextures from the continuum of morphologies we report. In Fig. 1, we further illustrate the spectrum of microtextures and mineral associations that Staudigel et al. (1) continue to overlook. This includes complex associations of titanite with other minerals, such and epidote, carbonate, and quartz supporting an abiogenic, metamorphic origin for the titanite. Moreover, Staudigel et al. ignore the microscale metamorphic temperature maps presented in refs. 2 and 5 that show lower chlorite temperatures around the titanite filaments recording retrograde cooling.

We reiterate that the titanite microfilaments are abiotic and not syngenetic to a 3.5-Ga subseafloor model and that Staudigel et al. (1) provide no new data to suggest otherwise. We reassert that the biological origin of the titanite microtextures be treated with caution (2), and that the search for the earliest traces of life must consider all abiotic scenarios before invoking biological processes.

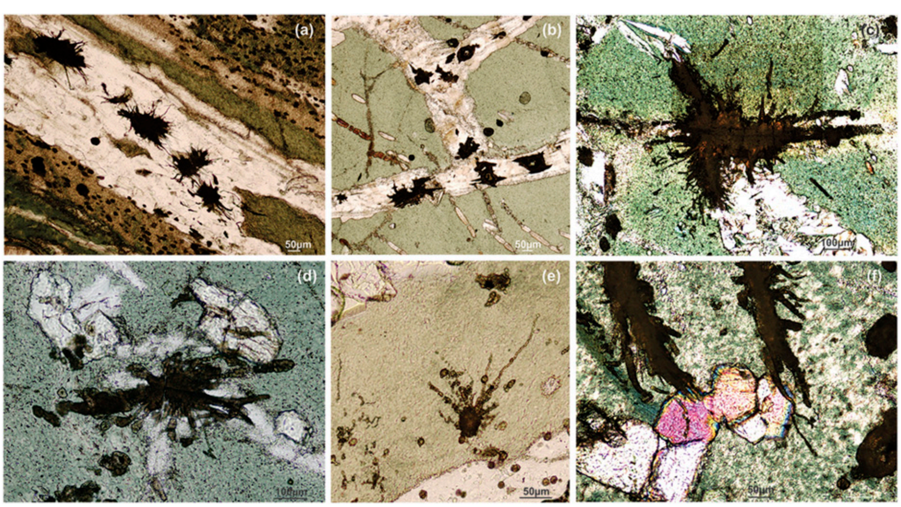

Fig. 1. Petrographic images of metavolcanic pillow lavas from a 183-m drill core in the approximately 3.5-Ga Hooggenoeg Formation (Barberton Greenstone Belt, South Africa), showing a continuum of titanite morphologies and filament sizes. The complex spectrum of titanite shapes, sizes, distributions, and mineral associations illustrated here and in Grosch and McLoughlin (2) support an abiotic metamorphic origin for the titanite, and contrasts with a bioalteration model of Staudigel et al. (1) that invokes delicate "signature" titanites of restricted morphology. (*A*) Titanite clusters with filaments of varying size contained within a quartz-carbonate band in interpillow breccia, unlike the chlorite-hosted variety reported in Staudigel et al. (1). (*B*) Titanite spheres with stubby, projections or spikes within an orthoclase feldspar band, not in chloritized glass. (*C* and *D*) Large, isolated, titanite porphyroblasts showing complex size and shape variation in their radiating filaments, which cross-cut matrix chlorite, quartz, epidote, and mica suggesting metamorphic titanite growth that postdates seafloor alteration. These textural observations support later titanite growth in one or more generations along with other metamorphic minerals, and do not support early titanite growth that filled in microtunnels on the seafloor. (*E*) A small titanite cluster with filaments of varying length and width with spotted hornfelsic texture titanite in the lower part of the image. (*F*) Titanite porphyroblasts in complex textural association with epidote. Late-stage approximately 2.9-Ga titanite filaments wrap around and intergrow earlier-formed epidote grain boundaries.

Eugene G. Grosch[1] and Nicola McLoughlin
Department of Earth Sciences, University of Bergen, N-5007 Bergen, Norway

Author contributions: E.G.G. and N.M. wrote the paper.

The authors declare no conflict of interest.

[1]To whom correspondence should be addressed. Email: geogene@gmail.com.

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