



## **Reply to comment on “Metamorphic origin of anastomosing and wavy laminas overprinting putative microbial deposits from the 3.22 Ga Moodies Group (Barberton Greenstone Belt)”**

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**Reply to comment on “Metamorphic origin of anastomosing and wavy laminas overprinting putative microbial deposits from the 3.22 Ga Moodies Group (Barberton Greenstone Belt)”**

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Anastomosing and wavy laminae are frequently observed in the ~3.22 Ga Moodies Group in the Barberton Greenstone Belt (BGB) (e.g., Heubeck, 2009; Homann et al., 2015). These laminae in sandstones accumulated in marine-terrestrial transitional environments have been extensively interpreted to be remnants of original microbial mats based, for instance, on lamina morphology and isotopic signals using outcrop samples from various localities in the BGB (e.g., Noffke et al., 2006; Heubeck, 2009; Homann et al., 2015; Homann et al., 2018; Thomazo et al., 2020). However, the influence of post-depositional processes on the lamina formation and preservation has received limited attention in previous studies. In order to bring further insights on the post-depositional history of the analyzed Moodies sandstones in light of the suggested biogenic origin of laminae, Saitoh et al. (2021) conducted detailed petrological observation and multiple geochemical analyses on samples collected from the Saddleback Syncline in the central BGB. Based on those results, Saitoh et al. (2021) illustrated important post-depositional processes and their substantial role in the lamina formation and modification. Saitoh et al. (2021) emphasized that their observations did not exclude the possibility that some of the analyzed Moodies laminae were originally microbial mats. Furthermore, conclusions of this work were based solely on the analyzed sandstones collected from one outcrop from the Saddleback Syncline. Nonetheless, Homann and Heubeck (2021) contested the significance of these outcomes in

providing further insights into the origin of Moodies anastomosing and wavy laminae.

The origins of the Moodies laminae and of carbonaceous material (CM) within these laminae should be separated clearly to discuss their biogenicity. The comments by Homann and Heubeck (2021) were based, at least in part, on misunderstanding on this point. For example, Homann and Heubeck (2021) used the term “carbonaceous laminae/laminations” repeatedly on their comments to impress their biogenicity on a reader. It is obvious that some of the Moodies laminae at other localities analyzed in previous studies are “carbonaceous” (e.g., Homann et al., 2018). However, almost all the laminae in the Saddleback sandstones analyzed in Saitoh et al. (2021) are not suitable to be described as “carbonaceous”, because CM is only rarely observed within the laminae as clearly shown by the Raman analyses. The scarcity of CM is underpinned by both the low total organic carbon (TOC) contents measured in three samples ( $< 108$  ppm; mean TOC =  $90 \pm 31$  (2SD,  $n=3$ ) ppm) and the low loss of ignition (LOI) measured in twenty-nine samples from all subunits (LOI  $< 2.5$  wt.%; mean LOI =  $1.1 \pm 1.0$  (2SD,  $n=29$ ) wt.%) (Saitoh et al., 2021). As a matter of comparison, the TOC contents of banded cherts are up to 2.2 wt.% in the older Hooggenoeg Formation and  $\sim 0.2$  wt.% in the Buck Reef Chert (e.g., Hofmann and Bolhar, 2007; Hofmann et al., 2013). In addition to the CM scarcity observed in the Moodies sandstones (Saitoh et al. 2021), multiple lines of evidence demonstrate that substantial secondary overprints, such as sericite and Ti-oxide occurrences, are commonly observed in the laminae through the analyzed succession. Based on these observations, Saitoh et al. (2021) concluded that the observed laminae, at the hand-specimen scale, in the analyzed rocks were features of the secondary overprints of later metamorphic processes (i.e., abiotically; also see Bower, 2011).

It is worth noting that the results in Saitoh et al. (2021) do not exclude – but do not support either – the possibility that precursors of some of the analyzed laminae were microbial mats. Indeed, the analyzed sericite-rich laminae contain finer clastic grains compared to the underlying and overlying coarser sediments; such textures suggest that they are an original sedimentary bedding. The rare CM observed within the laminae could have been a remnant of original microbial mats, although there is no evidence to exclude other possible sources (e.g., detrital organic matter) (Saitoh et al., 2021). In short, the petrological indices of biogenicity of the laminae are meager in the analyzed samples because they have been too modified to deliver strong, reproducible, and obvious original information. Therefore, the conclusion of Saitoh et al. (2021) is fully in line with recent publications aiming to illustrate and understand the complexity and potential heterogeneity of post-depositional processes on the Moodies sediments (Reimann et al., 2021; Janse van Rensburg et al., 2021). The degree of alteration in the Moodies group has been recently demonstrated to be highly heterogeneous and variable on a regional scale (Reimann et al., 2021), particularly in association with the density of diabase dyke network in the Saddleback Syncline (Fig. 1). In that sense, Saitoh et al. (2021) emphasized again that their conclusions were based solely on the analyzed sandstones from one outcrop of the Saddleback Syncline and should not be expanded to the entire Moodies Group.

Secondary Ti oxides and sericite cements are consistently dominant in anastomosing and wavy laminae through the analyzed succession (Saitoh et al., 2021). Moreover, the multiple sulfur isotopic composition of sandstones is relatively homogeneous through the analyzed Saddleback succession (Saitoh et al., 2020), and very similar to the isotopic composition of metasomatic sulfides from nearby gold mines in the central BGB (Agangi et al., 2016), suggesting that the secondary addition of hydrothermal, sulfur bearing-fluids also participated in the geological history of the Moodies Group in the Saddleback Syncline. The mineralogical and geochemical homogeneity of the analyzed sandstones (Saitoh et al., 2020, 2021) suggests that a regional post-depositional process has affected the Moodies sedimentary rocks around the studied section. Bearing this in mind, our conclusion was built on the description of rocks from the same locality – i.e., Log 9 – of Homann et al. (2015). Our field work was guided by a sedimentological approach and the completion of a sampling log. We were able to reproduce the facies succession described in Log 9 of Homann et al. (2015) and the samples were collected based on this lithofacies correspondence (see Figs. 1 and 2 and Table 2 of Saitoh et al., 2021). We disagree with Homann and Heubeck (2021)’s claim that our samples were “selectively investigated, and interpreted with scant consideration of their geological context”. Our study site was selected following personal communication with M. Homann and C. Heubeck and also according to the “Geology of the Barberton Greenstone Belt: Processes on the early Earth” excursion field guide of Heubeck et al. (2016). Although Homann et al. (2015) did not report precise sample positions along their logs, Fig. 1 shows that our samples are from the same locality in the Saddleback Syncline as in Homann et al. (2015). Similar lithology of the analyzed rocks from the same locality with the same geological context in Homann et al. (2015) and in Saitoh et al. (2021) indicates clearly that we did not use the least promising samples (in terms of putative biogenicity) as suggested by Homann and Heubeck (2021). Nevertheless, we also note that such “least promising” rocks should not be overlooked in general, because Archean altered rocks record complex post-depositional histories in various regional contexts and are useful to avoid leading a wrong perspective on early (and possibly extraterrestrial) life.

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Figure Caption

Fig. 1. Locality of the studied section in Saitoh et al. (2021). (A) Map showing the distribution of “microbial laminations” and rock silicification degree along the southern limb of the Saddleback Syncline (Reimann et al., 2021). (B) Google Earth satellite image of an enlarged square in A, showing the studied section in Saitoh et al. (2021). A diabase dyke is based on Lowe et al. (2012).

