FRAMBOIDAL PYRITE SHROUD CONFIRMS THE 'DEATH MASK' MODEL

FOR MOLDIC PRESERVATION OF EDIACARAN SOFT-BODIED ORGANISMS –

REPLY

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Thin, laterally extensive veneers of framboidal pyrite on fossiliferous bedding planes in eastern Newfoundland, Canada, provide evidence for post-burial microbially-mediated pyritization of the seafloor in the late Ediacaran Period (Liu 2016). Pyrite is inferred to have formed on the external surfaces of soft-bodied organisms and microbial matgrounds as a result of bacterial sulfate reduction, consistent with the 'death mask' taphonomic model for Ediacaran moldic preservation (Gehling 1999). Retallack (2017) accepts the evidence presented by Liu (2016) for early diagenetic pyritization of bedding planes in Newfoundland, and seems to offer at least tacit acceptance of evidence for modern oxidation of that pyrite, its widespread occurrence in global Ediacaran localities, and the potential influence of sedimentary pyrite burial on global Ediacaran oxygen concentrations. However, Retallack questions whether the presence of such pyrite veneers can be taken to demonstrate the 'death mask' taphonomic model, and specifically queries the source of the observed pyrite.

The data presented by Liu (2016), in addition to geochemical evidence from the same sections that suggests pyrite formation occurred via microbial sulfate reduction within a biofilm (Wacey et al. 2015), are entirely consistent with the hypothesized operation of the 'death mask' model. Multiple authors have now presented evidence for late Ediacaran pyrite

26   veneers (e.g. Dzik 2003), or the oxidized products of such laterally extensive veneers, on

27   fossiliferous surfaces and fossils (e.g. Gehling 1999; Mapstone and McIlroy 2006;

28   summarised in Liu 2016). Retallack is correct that none of the original petrographic thin

29   sections presented by Liu (2016) were taken through macrofossil specimens, but this is

30   because legislation restricts the collection and destructive analysis of Ediacaran fossil

31   material in Newfoundland. Identical iron-oxide veneers to those shown in thin sections

32   through non-fossil-bearing regions of fossiliferous horizons (e.g. Liu 2016, figs 2B, 3, 4A–D)

33   are observed directly on top of unpyritized positive and negative epirelief fossil impressions

34   on the same surfaces (e.g. Liu 2016, fig. 3A–B). This strongly suggests that the petrological

35   evidence presented from non-fossiliferous regions of bedding planes faithfully reflects

36   conditions immediately above macrofossil specimens. This can reasonably be interpreted as

37   evidence that the pyrite veneers originally covered both the seafloor and the external surfaces

38   of macro-organisms.

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40   No quantitative support is provided for the assertion (Retallack 2017) that <1.5mm-thick

41   pyrite veneers would have been too thin to preserve impressions of unpyritized Ediacaran

42   organisms. Tarhan et al. (2016) have similarly questioned whether sufficient pyrite, or sulfide

43   precursors, could be formed during the early stages of diagenesis to mold an impression of

44   soft-tissues before their removal by decay processes. Existing data suggest that in the

45   presence of microbial communities, sulfides are generated within 24 hours around buried

46   metazoan carcasses, and faithful impressions of external morphology can be obtained even in

47   freshwater experimental conditions with limited sulfate availability (Darroch et al. 2012).

48   This aspect of the 'death mask' model requires additional experimental constraint, but in

49   marine conditions, where sulfate concentrations are higher and concomitantly support

50   increased sulfide production during necrosis, it is considered likely that sulfides would form

51 rapidly around buried carcasses. Retallack's discussion of the thickness of anthropological

52 death masks is a semantic diversion.

53

54 The alternative taphonomic scenario presented by Retallack (2017) invokes pyrite

55 permineralization of soft tissues, and relies on both questionable data from thin sections

56 claimed to be taken through Ediacaran macrofossils (Retallack 2016a), and the model-driven

57 assumption that Ediacaran fossil-bearing sections in Newfoundland comprise intertidal or

58 supratidal facies. The thin sections presented by Retallack (2016a) cannot be accepted as

59 evidence that fossils were pyrite permineralized or preserved as organic material, since that

60 publication does not provide any quantitative compositional data to confirm the presence of

61 the mineral phases the author reports. Furthermore, that publication fails to outline how the

62 structures interpreted as fossils (which remain buried) were identified, rendering claims that

63 they were compaction resistant, or even that they represent *bona fide* fossils, ambiguous. As

64 such, that petrographic data should be considered uninformative with respect to Ediacaran

65 taphonomy.

66

67 Importantly, the depositional environment of the Newfoundland fossil-bearing sections was,

68 as with other deposits hosting taxa of the soft-bodied Ediacaran macrobiota, unequivocally

69 marine. Such taxa are found globally within a broad range of lithologies, interpreted on the

70 basis of process-based sedimentological observations to include carbonate platforms, storm

71 wave-base deposits, and deep-marine turbidite-dominated siliciclastic successions (e.g. Wood

72 et al. 2003; Grazhdankin 2004; Grazhdankin et al. 2008; Gehling and Droser 2012; Chen et

73 al. 2014). Suggestions that many of these deposits instead comprise terrestrial or intertidal

74 paleosols (Retallack 2012, 2013, 2014, 2016b) have been refuted by numerous researchers,

75 who instead reiterate their marine nature (Callow et al. 2013; Xiao et al. 2013; Tarhan et al.

76   2015). The fossil-bearing Conception and St. John's Groups of eastern Newfoundland

77   comprise normally-graded, water-lain turbidites with partial Bouma sequences (e.g. Liu et al.

78   2014, fig. 2), as well as hemipelagites, pelagites and volcaniclastic sediments (Wood et al.

79   2003). Ediacaran macrofossils are found on the top surfaces of hemipelagites that overlie

80   turbidite beds (Brasier et al. 2013; Liu 2016). Indeed, the macrofossil-bearing BR5 surface

81   described and figured by Liu (2016) as having a thick pyrite veneer lies on a hemipelagite

82   within the lower-middle Briscal Formation: a section considered by Retallack prior to the

83   discovery of fossils in these horizons to reflect beds "compatible with formation by

84   turbidites," and interpreted as being deposited in a marine setting (Retallack 2014, fig. 2).

85   Ediacaran macrofossils are found in abundance in these turbiditic deposits, just as they are in

86   other Ediacaran turbidite successions worldwide (e.g. the June Beds of the Mackenzie

87   Mountains, NW Canada [Narbonne et al. 2014] and the Charnian Supergroup of England

88   [Noble et al. 2015, *contra* Retallack 2012, 2017]). Since all sedimentary successions with

89   Ediacaran macrofossils are interpreted as marine, pyrite permineralization in modern and

90   Phanerozoic intertidal and supratidal settings represents an inappropriate comparison for

91   discussions of Ediacaran moldic preservation. The original assertion that widespread

92   pyritization of entire bedding planes in Newfoundland was unique to Ediacaran marine

93   settings (Liu 2016) therefore remains valid, though it is noted that examples of 'Ediacaran-

94   type' cast and mould preservation of individual organisms or areas of limited lateral extent

95   are documented from Phanerozoic marine settings (see references in Tarhan et al. 2016).

96

97   In summary, the arguments of Retallack (2017) are not sufficiently robust to refute the pyrite

98   'death mask' model for moldic preservation of Ediacaran soft-bodied organisms, and his

99   alternative taphonomic hypothesis invoking pyrite permineralization lacks sufficient

100   evidential basis in Newfoundland. Experimental work is now required to confirm the validity

101 of the 'death mask' model, and to determine ancillary factors such as the thickness of the

102 pyritic veneer necessary for moldic preservation of soft-bodied organisms, and the potential

103 role of clay minerals in suppressing decay (McMahon et al. 2016). Only by seeking to

104 actively resolve these taphonomic questions will we improve our understanding of Ediacaran

105 preservational processes and the biology of the Ediacaran macrobiota.

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