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Deep-water first occurrences of Ediacara biota prior to the Shuram carbon isotope excursion in the Wernecke Mountains, Yukon, Canada

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Summary

Ediacara-type macrofossils are known to appear as early as ~570 Ma in deep-water slope facies of the Avalon Terrane of Newfoundland (Pu et al. 2016). Whether they had their evolutionary origins in this setting (as opposed to simply being recorded there first), and the timing of origination relative to the Shuram carbon isotope excursion (CIE), remain open questions. Our ability to assess whether this deep-water origination is a genuine reflection of evolutionary succession, an artifact of an incomplete stratigraphic record, or a bathymetrically controlled biotope is fundamentally limited by a lack of geochronological constraints and detailed shelf-to-slope transects of Ediacaran basins.

The Ediacaran Rackla Group in the Wernecke Mountains of NW Canada represents an ideal shelf-to-slope depositional system to understand the spatiotemporal and environmental context of Ediacara-type organisms' stratigraphic occurrences. New sedimentology and carbonate carbon isotope data from the Rackla Group establish a stratigraphic framework tying shelfal strata in the Goz Creek area into lower slope deposits in the Rackla belt area. Further, the Shuram CIE is demonstrably present in shallow shelf to slope deposits and provides a robust regional and global time marker that links these two regions (Moynihan et al. 2018). New discoveries of numerous hold-fast discs *Aspidella* indicative of frondose Ediacara organisms have been found in deep-water slope deposits of the Nadaleen Formation (formerly 'June beds') below the Shuram CIE in the Rackla Belt, but are notably absent in coeval shelfal strata in the Goz Creek region. In contrast, new Ediacara-type fossils (including juvenal fronds, *Beltanelliformis*, *Aspidella*, and multiple ichnotaxa) are found above the Shuram CIE in the Blueflower Formation in both deep-water and shallow-water deposits. The presence of pre-Shuram CIE Ediacara-type fossils occurring only in deep-marine facies within a basin that has equivalent shallow-water facies provides the first evidence support a deep-water origination for the Ediacara biota.

Field and Analytical Methods

Geological mapping, stratigraphy, and carbon isotope sampling were conducted in the Wernecke Mountains over field seasons in 2017 and 2018. These data enabled the linking of stratigraphic sections of Rackla Group strata across a ~100 km long shelf-slope transect with isotopic measurements of $\delta^{13}C$, $\delta^{18}O$ made on carbonate rock samples at meter-scale resolution. Data was collected over multiple camps located in areas with well-exposed and laterally extensive panels of the Ediacaran and lower Paleozoic strata in the shallow shelfal facies of the Goz Greek area and deep-water slope and basinal facies in the Rackla region in the Wernecke Mountains. Relevant strata were mapped, measured and described in detail to record sedimentary facies and structures, fossil preservation potential, and confirm the presence/absence of fossils. Conventional photography and unmanned aerial vehicles (UAVs) were used to photograph outcrop features at bed scale and also track bed geometries over hundreds of meters to interpreted depositional architecture. Camps were accessed by fixed-wing aircraft from Mayo, Yukon, along with helicopter transport coordinated by ATAC Resources Ltd. Additional helicopter support was provided by the Geological Survey of Canada (GSC).

All $\delta^{13}C_{carb}$ and $\delta^{18}O$ isotopic data were produced at either Stanford University or Dartmouth College using a Finnigan GasBench coupled to a Delta^{plus}XL mass spectrometer. Samples were cut perpendicular to bedding using a water saw and micro-drilled (~2-5 mg powder) to avoid secondary cements and veining. External precision (1σ) of $\delta^{13}C_{carb}$ and $\delta^{18}O$ was <0.1‰.

Conclusions

The presence of pre-Shuram CIE Ediacara-type fossils occurring only in deep-marine facies within a basin that has equivalent shallow-water facies provides the first evidence support a deep-water origination for the Ediacara biota. Given existing age constraint on the Shuram CIE, it appears that Ediacaran organisms may have originated in the deep ocean for up to ~15 Myr before migrating into shelfal environments in the terminal Ediacaran. It remains uncertain why these organisms originated in aphotic, deep-marine environments which in the modern ocean have very little food. However, given that the Ediacaran ocean after the Marinoan deglaciation was likely very warm and dominated by widespread low oxygen conditions, the deep-water pattern observed in the Wernecke Mountains and elsewhere are the world may potentially be a product of early eukaryotes seeking refuge from temperature-induced hypoxia in the hot, low pO_2 Ediacaran surface ocean (Boag et al. 2018).

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