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Chemostratigraphy of the Ediacaran Gametrail Formation across a shelf-slope transect in the Wernecke Mountains, Yukon, Canada

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Summary

The Ediacaran Shuram carbon isotope excursion (CIE) represents the largest negative $\delta^{13}C_{carb}$ excursion in Earth's history. Despite considerable research attempting to explain a mechanistic driver for this event, there remains little consensus on the origin and diagenetic history of this CIE, with growing speculation as to whether it represents a primary perturbation to the global marine inorganic carbon reservoir. Here, we examine the Shuram-bearing Gametrail Formation across a shelf-slope transect in the Wernecke Mountains of Yukon, Canada, to elucidate the geochemical and sedimentary expression of this CIE.

Thirteen detailed stratigraphic sections were measured of the Gametrail Formation across an approximately 100-km-long depositional transect with meter-resolution sampling of carbonates for various isotopic analyses. The Gametrail Formation increases in thickness by more than four-fold from the most proximal (73.3 m) to the most distal (301.4 m) locations along the shelf-slope transect. Over 1000 $\delta^{13}C_{carb}$ measurements have been made with selected samples being analyzed additionally for $\delta^{44/40}Ca$, $\delta^{26}Mg$, and major/trace element geochemistry. Along the shelf-slope transect, there is an ~10‰ $\delta^{13}C_{carb}$ shift in the nadir of the Shuram CIE between proximal and distal locations, which is expressed within a diversity of sedimentary facies representing sedimentation along a distally steepened carbonate ramp. Shallow-water stratigraphic sections are characterized by dolostone-dominated facies with $\delta^{13}C_{carb}$ values reaching a nadir of ~ -5.5‰, with generally more enriched $\delta^{44/40}Ca$, lower Sr/Ca, and higher Mg/Ca ratios. In contrast, slope to basin floor sections are dominantly composed of limestone-dominated facies with $\delta^{13}C_{carb}$ measurements reaching a nadir of approximately -15‰ and more depleted $\delta^{44}Ca$, higher Sr/Ca, and lower Mg/Ca ratios.

These preliminary data largely agree with diagenetic trends suggested from geochemical modeling studies of Ahm et al. (2018, 2019) and observations from a modern carbonate platform (Higgins et al., 2018), which predict enhanced fluid flow towards the platform interior resulting in more fluid-buffered diagenesis. These more fluid-buffered conditions move $\delta^{44/40}Ca$ towards the composition of seawater (~0‰) and variably elevate $\delta^{26}Mg$ values. These coupled changes in $\delta^{44/40}Ca$ and $\delta^{26}Mg$ are the same observed along our shelf-slope transect, with progressively more enriched $\delta^{44/40}Ca$ values moving from the deep-water Rackla location to the shallow-water Goz A location. In summary, these data distinguish diagenetic conditions experienced in shallow vs. deep-water carbonate settings in northwestern Laurentia and identify a critical relationship in the nature and magnitude of the Shuram CIE between inner ramp and upper slope settings.

Field and Analytical Methods

Geological mapping, stratigraphic sections, and chemostratigraphic sampling were employed in the Wernecke Mountains of Yukon, Canada, over the summers of 2017, 2018, and 2019. The completed field work focused on linking stratigraphic sections of the Ediacaran Gametrail Formation across a ~100-km-long shelf-slope transect with isotopic measurements of $\delta^{13}C$, $\delta^{18}O$, $\delta^{44/40}Ca$, and $\delta^{26}Mg$ made on carbonate rock samples collected at meter-scale resolution. Conventional photography and unmanned aerial vehicles (UAVs) were used in most field areas to capture photographs of rock exposures, sedimentary facies and structures, and fossils.

Field seasons included nine camps situated within a well-exposed and laterally extensive panel of upper Ediacaran and lower Paleozoic strata in the Goz Creek and Rackla areas in the Wernecke Mountains. Camps in the Wernecke Mountains were accessed by fixed-wing aircraft from Mayo, Yukon, followed by helicopter support in coordination with ATAC Resources Ltd. at their Nadaleen property, as well as through support from the Yukon Geological Survey (YGS) and Geological Survey of Canada (GSC).

Carbonate rock samples from northwestern Canada have been analyzed at both Dartmouth College and the Yale University Analytical and Stable Isotope Center for $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$. $\delta^{44/40}Ca$, $\delta^{26}Mg$, and major/trace element analyses were performed at Princeton University.

Conclusions

The significance of these preliminary results is that the most depleted $\delta^{13}C_{carb}$ values recorded in the Gametrail Formation (-15‰), are found in slope limestones which have very high Sr/Ca ratios (approaching ~5 mmol/mol) and $\delta^{44/40}Ca$ values similar to that expected from the precipitation of primary aragonite from seawater ($\delta^{44/40}Ca$ ~ -1.5‰). Moving towards the platform interior dolostones, the nadir of the Shuram CIE becomes more enriched and $\delta^{44/40}Ca$ values indicate more fluid-buffered diagenetic conditions. These preliminary data suggest that the highly depleted values identified in slope limestones of the Gametrail Formation are not diagenetic in origin, and the shift to more enriched $\delta^{13}C_{carb}$ values in progressively shallow-water locations can be attributed in part to more fluid-buffered diagenetic conditions experienced on the platform interior. These preliminary data characterize the diagenetic conditions experienced in shallow- vs. deep-water carbonate settings in northwestern Laurentia and highlight a critical relationship in the nature and magnitude of the Shuram CIE in different depositional settings.

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