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The Carolina Terrane as a record of redox conditions and nutrient cycling in the Iapetus Ocean during early animal evolution

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Metasedimentary successions associated with the Carolina Terrane span from the Ediacaran through the middle Cambrian, and thus record conditions in the Iapetus Ocean during the diversification of early animal phyla. This study focuses on samples of Albemarle Group metasediments collected from four sites within the New London Syncline in central North Carolina, supplemented by samples from additional sites in central South Carolina. While these sediments are metamorphosed to lower greenschist facies, and have developed variable degrees of foliation or rock cleavage, many parts of the succession preserve fine-scale sedimentary structures, including graded microturbidites and millimetric (likely microbial) laminae. Hummocky cross stratification and soft sediment deformation indicate deposition of Ediacaran sediments at or below storm wave base. Lower Cambrian sediments are generally sandier, and at some sites include domal stromatolites indicating deposition in the photic zone.

Iron speciation analysis reveals transitions between apparently oxic conditions, with little reactive iron present, and ferruginous conditions, with the reactive iron pool dominated by oxides. While virtually no pyrite is present in outcrop samples, samples from the apparently ferruginous intervals contain coarse (~1 mm) euhedral pyrite pseudomorphs, suggesting that what is present today as oxides may reflect a history of pyrite formation in the burial environment. Despite this evidence for anoxia, redox-sensitive trace elements (primarily Mo, U, and V) are consistently depleted below crustal levels.

Nitrogen isotope results indicate an aerobic nitrogen cycle was in place within the surficial Iapetus Ocean during the Ediacaran, with nitrogen isotope values comparable to those seen in Paleozoic greenhouse intervals. A shift toward lower values in the Lower Cambrian may indicate either an increased role of nitrogen fixation, or a greater contribution of ammonium assimilation to productivity. Given the lack of evidence for increasing inventories of the trace element cofactors enabling diazotrophy, this may indicate that fixed nitrogen was advected from other parts of the global ocean, and that, while trace metals may have begun to build up in shallow oxic water masses by the middle Cambrian, dissolved trace metal inventories remained low in the distal open-ocean environments represented by the Carolina Terrane.