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The stratigraphic relationship between the Shuram carbon isotope excursion, the oxygenation of Neoproterozoic oceans, and the first appearance of the Ediacara biota and bilaterian trace fossils in northwestern Canada

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ABSTRACT

A mechanistic understanding of relationships between global glaciation, a putative second rise in atmospheric oxygen, the Shuram carbon isotope excursion, and the appearance of Ediacaran-type fossil impressions and bioturbation is dependent on the construction of accurate geological records through regional stratigraphic correlations. Here we integrate chemo-, litho-, and sequence-stratigraphy of fossiliferous Ediacaran strata in northwestern Canada. These data demonstrate that the FAD of Ediacara-type fossil impressions in northwestern Canada occur within a lowstand systems tract and above a major sequence boundary in the informally named June beds, not in the early Ediacaran Sheepbed Formation from which they were previously reported. This distinction is substantiated by $\delta^{13}C_{carb}$ chemostratigraphy of the Sheepbed carbonate, which overlies the Sheepbed Formation, and the Gametrail Formation, which overlies the June beds. The Sheepbed carbonate hosts heavy $\delta^{13}C_{carb}$ values whereas the Gametrail Formation contains a large $\delta^{13}C_{carb}$ excursion, which we correlate with the globally recognized Shuram excursion. Stratigraphically above the Gametrail excursion, the first bilaterian burrows are present in the basal Blueflower Formation. Together, these data allow us to construct an age model for Ediacaran strata in northwestern Canada and conclude that a purported shift in Fe speciation in the Sheepbed Formation significantly predates the shift recorded above the ca. 582 Ma Gaskiers glaciation in Newfoundland and the first appearance of Ediacaran biota.

The Gametrail excursion shares many characteristics with Shuram negative $\delta^{13}C_{carb}$ excursion: 1) $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ covary; 2) $\delta^{13}C_{carb}$ and $\delta^{13}C_{org}$ do not covary; 3) the excursion is developed during a transgressive systems tract and recovers in an highstand systems tract; and 4) values in some sections are well below mantle $\delta^{13}C$ input values but are variable between sections. We relate regional lateral variability in the magnitude and character of this excursion to condensation and diachronous deposition during the transgression and local authigenic carbonate production. In light of these observations, we explore a variety of models for the genesis of the Shuram excursion and suggest that the location and amount of authigenic carbonate production played a role in the excursion.

1. Introduction

Ediacaran strata are exposed in the Ogilvie, Wernecke, and Mackenzie Mountains of northwestern Canada. These mixed carbonate–siliciclastic successions host a rich paleontological record characterized by abundant Ediacara-type fossil impressions and bilaterian trace fossils (e.g. Narbonne and Hofmann, 1987; Hofmann et al., 1990; Narbonne and Aitken, 1990; Narbonne, 1994; Narbonne and Aitken, 1995; MacNaughton and Narbonne, 1999); as such, these deposits provide an ideal natural laboratory to test proposed models for the evolution of late Proterozoic marine biogeochemistry. However, unlike other Ediacaran successions, it has been suggested that the Shuram negative carbon isotope excursion — a critical benchmark for understanding Ediacaran geochemical cycling and temporal constraints — is not present in northwestern Canada (Derry, 2010). The apparent absence of this anomaly may reflect the degree to which the event is global or confounded by regional isotopic variability (e.g. Li et al., 1999; Xiao et al., 2004; Jiang et al., 2007), locally truncated within unconformities (MacNaughton et al., 2000, 2008), or not

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recognized due to the reconnaissance level of previous chemostratigraphic studies in the region (Narbonne et al., 1994; Kaufman et al., 1997). Mapping the global distribution and variability of the Shuram excursion is critical to understanding its origin and significance, in particular because it has been related to the oxygenation of the deep ocean (e.g. Fike et al., 2006). If the excursion was driven by an oxygenation event, we might expect intimate stratigraphic relationships between the Shuram excursion, oxygenation of the water column as

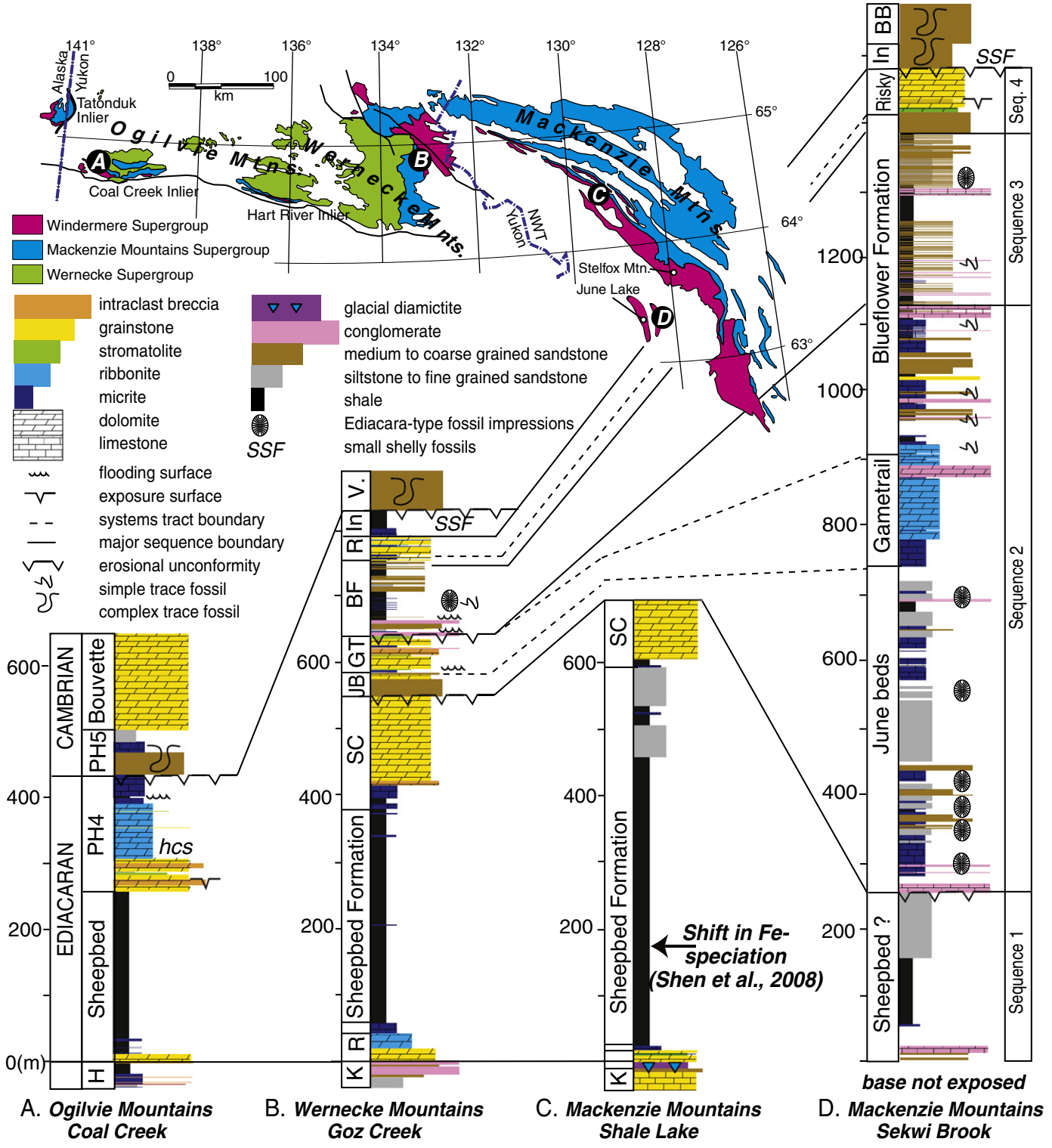

Fig. 1. Schematic Ediacaran stratigraphy across northwestern Canada with inset map documenting distribution of Proterozoic strata in the Ogilvie, Wernecke and Mackenzie Mountains (modified from Abbott, 1997). Locations A, B, C, and D on the map refer to the different key localities shown in the schematic stratigraphic sections below and discussed at length in the text. H = Hay Creek Group, K = Keele Formation, R = Ravensthroat Formation, SC = Sheepbed carbonate of the Sheepbed Formation, JB = June beds, BF = Blueflower Formation, GT = Gametrail Formation, R = Risky Formation, In = Ingta Formation, BB = Backbone Ranges Formation, V = Vampire Formation.