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Precambrian–Cambrian transition: Death Valley, United States: Comment and Reply

Frank A. Corsetti
Department of Geological Sciences
University of California
Santa Barbara, CA 93106

James W. Hagadorn
Department of Geological and Planetary Sciences
California Institute of Technology
Pasadena, CA 91125

We thank Graham for alerting Geology readers to his work in Mongolia, and for his comment on our manuscript. Although we are puzzled by his suggestion of “errors and omissions” (and even naughtiness!) in our article, we will attempt to clarify some of his concerns.

First, it is important to note that our manuscript was not an attempt to tout the Death Valley section as the “best”, most critical section in the world. Rather, we feel that any section that contains both a basal occurrence of *Treptichnus pedum* and another means for correlation (in this case, carbon isotopes) is critical. The Mongolian succession contains an excellent chemostratigraphic and biostratigraphic record which has proved pivotal in clarifying long-standing problems regarding interregional correlation (Brasier et al., 1996). However, Graham fails to mention that the Mongolian succession does not contain a *basal* Cambrian occurrence of *T. pedum* (Goldring and Jensen, 1996), which is the key criterion for correlating the Precambrian-Cambrian boundary to the Global Stratotype Section and Point (GSSP) in Newfoundland. Furthermore, although we are loathe to adopt Graham's approach and criticize data from a section we have never studied or visited, Graham is incorrect when he states that there are three sections in Mongolia where negative excursions are constrained by *T. pedum*. In fact, only one unit in one Mongolian section (Bayan Gol) contains non-dubiofossil occurrences of *T. pedum*, and these occur "mainly as float" (Goldring and Jensen, 1996) two units (~350 m) *above* what is considered the negative $\delta^{13}C$ Precambrian-Cambrian (PC-C) boundary excursion (Brasier et al., 1996). In Death Valley, there are over a dozen easily accessible sections exposed in numerous mountain ranges within the ~1000 km^2 Death Valley region. – *all* of which contain abundant *T. pedum* and negative isotopic excursions at the same horizon (e.g., Hagadorn and Waggoner, 2000).

Second, why is it pertinent in this debate to point out the *lack* of small shelly fossils (SSF) in the Death Valley succession? SSF have no bearing on correlations in our manuscript, and are clearly irrelevant for other key sections such as Australia and the GSSP itself in Newfoundland. We again prefer to focus on the positive: i) the *presence* of critical Phanerozoic-style trace fossils interbedded with carbonates recording a negative carbon isotope excursion (including a basal occurrence of *T. pedum*); ii) the presence of *Cloudina* and other Ediacaran fossils below the boundary excursion (Langille 1974a,b; Horodyski, 1991; Hagadorn & Waggoner, 2000); and iii) the lack of unconformities within the succession containing the Precambrian-Cambrian transition interval.

Third, while Graham berates us for our discussion of sample alteration, once again choosing to see the "glass as half empty", he neglects to point out the positive. For example, the $\delta^{18}O$ signature, commonly used in similar studies to aid in the evaluation of alteration (e.g., Shields, 1999), is quite good for all but one of the samples and *does not* co-vary with $\delta^{13}C$; in general, covariance is considered an indication of alteration. We find it even more compelling that the Death Valley isotopic pattern is observed across facies boundaries: it is highly unlikely that samples from a spectrum of paleoenvironments would undergo the exact same diagenetic alteration across the *entire* basin in order to create a false negative isotopic excursion!

Fourth, we are apparently chastised for using a space-saving composite stratigraphic section in our manuscript (fig. 3), very much like the composite stratigraphic sections utilized in Shields (1999) and other chemostratigraphic studies. In fig. 2 of our manuscript we present the data from the individual sections used to compile the composite section. The individual patterns are identical to the patterns in the composite section. Note also that the correlation between Death Valley and the Mackenzie Mts. was based on two different datasets: *biostratigraphy* in conjunction with *chemostratigraphy* (not mere "wiggle matching"). Of course, other datasets would be nice (Sr isotopes, $\delta^{13}C_{org}$, for example), but the rock types preserved in Death Valley were not amenable to these techniques.

Lastly, the most puzzling point of contention raised in the comment is our choice of isotopic "tie-points". The source for each correlation point is clearly referenced in the chemostratigraphy section of our manuscript and our isotopic trends are nearly identical to the those suggested by Graham himself (Shields, 1999, fig. 3). That said, our data are clearly subject to multiple working hypotheses. Perhaps in the future Graham will provide some constructive alternative correlations for our data, much in the same way we suggested two possible alternative correlations in our Figure 3.

We view the Death Valley succession as a viable piece of the Precambrian-Cambrian boundary puzzle because it contains a relatively rare combination of stratigraphic information (trace fossils and carbon isotopes) within an accessible, conformable sequence that spans the onset of the Cambrian explosion. Much of the global warehouse of biologic and geologic information from this interval is housed in lithologically homogeneous successions, (e.g., siliciclastic-dominated sections like the GSSP in Newfoundland, or carbonate-dominated sections like Siberia or China). The biostratigraphic information and chemostratigraphic potential of these sections are vastly different; biostratigraphically useful trace fossils typically occur in siliciclastics, whereas SSF and chemostratigraphic data are most commonly preserved in carbonates. Mixed siliciclastic-carbonate successions (e.g., Death Valley, the Mackenzie Mts., and Mongolia) are important because they allow us to make robust comparisons between these lithologic end members, because they provide the basis for correlating the PC-C boundary across continent fragments, and because they provide a framework for assessing the critical evolutionary events of this interval.

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