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A new approach to quantifying stratigraphic resolution, integrating chemostratigraphic data, and testing global stratotypes

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Global Stratotype Sections and Points (GSSPs) should yield a range of data relevant for long-distance correlation, including a diversity of fossil occurrences, as well as chemostratigraphic events and other types of stratigraphic markers. Although there are several methods available for integrating multiple datasets into a correlation project (e.g., graphic correlation and constrained optimization (CONOP)), relatively few studies have employed these methods specifically as part of the process of selecting GSSPs. Horizon Annealing (HA) is a recently developed method that simultaneously integrates data from multiple stratigraphic successions and uses a simulated annealing algorithm to order sample horizons from multiple sections into a single composite succession. In doing so, it provides a correlation of all horizons among all of the sections, based on all of the data from each sample, which minimizes the misfit between the composite succession and the data from each of the individual sections. Since GSSPs are, by definition, sample horizons, HA is well suited to the task of correlation of the GSSPs with correlative levels in other sections.

We have examined the correlation of the GSSPs for the bases of the Hirnantian Stage (uppermost Ordovician) and the Silurian System using 27 relatively graptolite-rich sections on four paleo-continents spanning the time interval from late Katian into mid-Rhuddanian using HA. Ten of these sections have available C isotope data and three provide S isotope data. Our study interval is marked by a prominent, global positive C isotope excursion, the Hirnantian Isotopic Carbon Excursion (HICE), and a coeval positive S isotope event. We have recognized and coded the stratigraphic intervals of the rising and falling limbs of the HICE and treated these intervals in a manner similar to the ranges of fossil taxa. In this way, the occurrences of these intervals changing isotopic values provide additional constraints on the placement of those horizons and sections within the composite.

We used two independent methods within HA to investigate the level of precision with which particular horizons can be constrained within the composite succession. Jackknife analysis, replicate analyses with individual sections randomly omitted from the dataset, provides a statistical measure of the range of variability or error in the placement of sample levels within the composite. Relaxed fit analysis, which assesses the range of variation recorded as the optimality-of-fit criteria are slightly relaxed, allows for a second assessment of the degree of constraint of each sample level within the composite. Our study shows that incorporation of the chemostratigraphic data dramatically improves the resolution of placement of sample horizons within the composite throughout our study interval, compared with using biostratigraphic data alone.

Our conclusions suggest that the GSSPs for these boundaries are relatively well-constrained relative to other sections and levels in the composite that were considered for these GSSPs. In addition, we can infer that the mean temporal resolution for sample horizons in the composite is approximately +/- 160 Ka.