The interplay of stratigraphic architecture and ecological gradients: the oft-overlooked control on the stratigraphic occurrence of fossils

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Abstract

Modeling and field studies have demonstrated the overarching control stratigraphic architecture has on the occurrence of fossils. Hiatuses and changes in sedimentation rate are the two most easily and widely understood of these controls. Intuitively, they are important for the formation of many shell and bone beds, the local abundance of fossils, but also simply the presence of fossils. As a result, first and last occurrences of species are strongly tied to hiatuses (e.g., subaerial unconformities) and intervals of greatly lowered sediment accumulation rates (e.g., downlap surfaces such as flooding surfaces and condensed sections).

Often overlooked and less widely understood is a third important control: the interplay of stratigraphic architecture and the distribution of species along ecological gradients that are correlated with water depth and elevation. In modern marine systems, benthic taxa are widely documented to form communities whose distribution is correlated with water depth. Although water depth itself does not control these communities, the physical and chemical factors that do exert this control are highly correlated with water depth. As a result, water-depth gradients in community composition are not only ubiquitous, they are also commonly the strongest gradient that describes the distribution of benthic marine species. Because many nektic taxa have ecologies that are tied to the seafloor (e.g., demersal fish), they are also commonly distributed along gradients correlated with water depth, and this is also observed in many ancient clades (e.g., ammonites and conodonts). Because many planktic taxa have distributions that reflect stratified water masses, they too often have stratigraphic occurrences correlated with water depth (e.g., graptolites).

The correlation with water depth is crucial because water depth changes predictably with stratigraphic architecture, with gradual shallowing during progradational and degradational stacking, gradual deepening within retrogradational stacking, abrupt shallowing at surfaces of forced regression, and abrupt deepening at flooding surfaces. Although numerous field studies have demonstrated these patterns, this ecological control on fossil occurrences is commonly overlooked.

Recent modeling also suggests a similar relationship in nonmarine settings, in which nonmarine gradients in community composition correlated with elevation, widely demonstrated in the modern world, may also be expressed in the stratigraphic record. For example, a net upward gain in elevation is expected during shoreline regression, whereas a net upward decline in elevation is expected during transgression. Moreover, selective preservation of this

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nonmarine elevation gradient imparts a powerful and systematic control on the completeness of the nonmarine fossil record. The interplay of these community gradients correlated with water depth and elevation must be considered before any biological interpretation of the the stratigraphic occurrence of fossils can be made, such as at mass extinctions.

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