Building a pragmatic Phanerozoic eustatic sea-level curve from the rock record

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Abstract

The depiction of Phanerozoic eustasy was given momentum in the 1970's and 1980's by the well-known publications led by Exxon researchers Peter Vail and Bilal Haq. Since then, further research has continued to develop our understanding. For the Cenozoic, where proxies (e.g., δ18O values) for glacio-eustasy are available, the timing and magnitude of short-term eustasy is reaching consensus. However, for the Mesozoic and Palaeozoic geochemical proxies are at best unreliable, causing dependence on interpretation of the rock record. As the isolation of the eustatic signal from the sedimentary record is challenging, this has led to a divergence of opinions. Herein we present a simplified workflow that allows for the construction of a pragmatic short-term ("3rd order") Phanerozoic eustatic curve, for which the results can be tested by process-modelling to determine plausibility. The mid-Cretaceous is chosen as an example of the approach.

In most sedimentary sections one can observe vertical facies trends and changes in palaeobathymetry indicators. Additionally, in the subsurface and in some large-scale outcrops it is possible to recognise sedimentary architectures indicative of changes in relative sea level. These sets of information can be interpreted using a consistent sequence stratigraphic approach, which reduces uncertainty in understanding sea-level trends. For a given short time interval (e.g., a stage), the examination of multiple suitable stratigraphic sections in a global dataset can be used to identify a commonality (overlap) in the timing of major transgressive and regressive events, although some residual uncertainty will remain. A prerequisite to this is detailed work on biostratigraphic calibration between different fossil groups and other chronological techniques (e.g., δ13C excursions).

Having established timings of synchronous eustatic rise and fall, eustatic magnitude limits can be estimated from stratigraphic observations (e.g., measurements derived from erosional and depositional relief, fossil assemblages, facies juxtaposition), geochemical proxies (e.g., δ18O values) or from a compilation of published magnitudes. These can then be integrated with an independently calculated long-term eustasy trend, derived from tectonic, onlap and geochemical models, and the resultant curve analysed for plausibility. Here forward stratigraphic modelling can be powerful for assessing the impact of uncertainties in timing and magnitude on the generation of a plausible eustatic curve. We show that many published eustatic curves fail to adequately create plausible sedimentary models in that the pace of eustatic change depicted is unable to generate the partitioning of different systems tracts observed in the rock record.

A plausible, pragmatic Phanerozoic eustatic curve provides a valuable tool for not only understanding Earth systems processes through time (e.g., assessing the presence of polar ice to

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drive glacio-eustasy), but also for generating subsurface characterisation of lithological variation and heterogeneity. The latter is a major challenge of the 21st century energy transition, not least for identifying storage resource for CO2.

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