Bioturbation and sedimentation rates in prodeltas

Janok P. Bhattacharya

Susan Cunningham Research Chair in Geology, School of Geography and Earth Sciences, McMaster University

Summary

Bioturbation can be a highly useful tool in measuring short-term (annual to millennial) sedimentation rates, especially in shallow-shelf, marine settings close to river mouths. Depending on climate regime, rivers typically deposit deliver most of their sediment during flood periods, which are typically around 1-5% of the time. Flood recurrence intervals also vary with climate, and can range from every few years in arid or ephemeral setting to yearly in monsoonal settings.

The upward-coarsening progradational component of a parasequence potentially provides a robust and nearly complete *local* record of sediment delivery events and storms, although this is limited to the time it takes to prograde past a given point (i.e., probably < 1000 years). In smaller source-to-sink systems, such as the Cretaceous Western Interior of North America, large storms may affect the river catchment areas and the inner shelf simultaneously, driving rivers into a flood state. Such "Oceanic Floods" (Wheatcroft, 2000) result in wave-modified river plume deposits, and these can be reworked by later storms, but are not reworked by fair-weather waves, as they are deposited below fair-weather and above storm wave-base.

Detailed bed-by bed analysis of prodelta heterolithic facies in Cretaceous delta deposits, including the Dunvegan Formation in Canada; Ferron Formation in Utah, and Gallup Formation in New Mexico; show meters-thick successions of laminated to thinly bedded sandstones, siltstones and mudstones overlain by steeply-dipping delta front sandstones. The heterolithic facies show a Bioturbation Index that varies from 0-3, with rare intervals of higher bioturbation.

Trace fossils are typically rare and when present comprise simple and small forms, with markedly low diversity, although thin horizons with high abundance are also noted. The low abundance and diversity of trace fossils in heterolithic strata suggests a stressed physico-chemical environment, including salinity and turbidity, characteristic of river-dominated settings (MacEachern et al., 2005). Importantly, the lack of bioturbation also indicates that there were not long periods between events. Substrate recolonization periods, following an event such as an oceanic flood, are thought to on the order of several months to a year. The sporadic bioturbated horizons observed in cored sections with moderate to high abundance of low diversity and small, stunted trace fossils are interpreted to indicate opportunistic (*r*-selected) populations that exploit periods between events, but the frequency of events precludes the more diverse and robust ichnofauna characteristic of more stable environments. Assuming that these are indeed annual events, this would suggest a sedimentation rate of about 1 cm per year (10 m/1000 years). The observations of the common event beds and low bioturbation are consistent with the hypothesis that inter-event durations are less than a year in duration. Prodelta heterolithics thus represent a high-fidelity archive of the majority of events that occurred across an area of consideration over the few hundred to less than 1000 years that it takes for a "typical" parasequence to build a vertical facies succession. The regressive facies of the vertical facies

succession thus likely samples only about 2-4% of the total elapsed time of one Cretaceous parasequence.

In contrast, the transgressive facies that cap parasequences commonly show pervasive bioturbation and higher diversity and more robust trace fossils forms, suggesting less stressful, more stable (K-selected) environments (Pianka, 1970). Higher level of bioturbation is fundamentally ameliorated by orders-of-magnitude lower sedimentation rates. In other words, there is good evidence that much of the time in a parasequence is tied up in transgressive surfaces at the top, which record either bypass or non-deposition during the progradational phases, and/or subsequent transgressive reworking during the transgressive phase.

Observations of the prodeltaic facies successions indicate the high-fidelity nature of these stratigraphic records, as indicated by the numerous event beds and the overall limited bioturbation intensity, abundance and diversity. The notion that only larger “decadal” or “centennial” floods are recorded is not compatible with the low levels of burrowing. Non-deltaic shelf, shoreface and transgressive deposits in the Dunvegan and Ferron systems, show pervasive, robust, and diverse bioturbation and show that areas away from the river influence boast a fully marine biota. The fact that these biotas are inhibited from invading or colonizing the areas within delta lobes suggest that conditions in these deltaic centres were unrelentingly inimical to life, largely reflecting the relatively continuous nature of deposition.

Calculations of shelf-transits during progradation show that vertical accumulation rates of these prodeltas were on the order of 1 cm/year versus the transgressive facies in which sedimentation rates may be less than 1 mm/year. Counting of individual lamina and beds in the prodelta deposits demonstrate that events were likely recorded yearly. Times of massive discharge (e.g., decadal or centennial flood events) likely are recorded by thicker beds, whereas periods of lower discharge, such as might reflect droughts, may be indicated by the rare burrowed intervals. This invites the idea that vertical facies successions from river-dominated prodeltas may contain a reasonably complete record of storms and flood events, albeit for transit periods on the order of < 1000 years for the systems discussed. This invites the idea that high-fidelity prodeltaic facies successions may be used to analyse storm-flood frequencies and intensities in deep time systems.

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References

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