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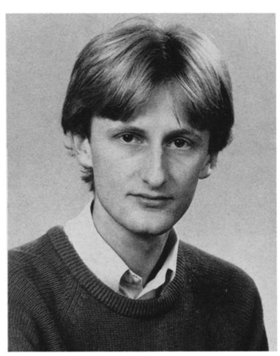
Anoxia and Mass Extinctions

There have been several attempts to attribute the many mass extinctions of the fossil record to the same cause. Of these, Steve Stanley's global cooling events and Tony Hallam's major eustatic regressions are the most plausible. However many mass extinctions do not coincide with cooling episodes. The opposite argument is often leveled at the regression model for the Phanerozoic record contains many more major regressions than there are mass extinctions. However some marked regressions are followed by spectacularly rapid transgressions associated with the spread of anoxia over broad areas of the shelves. It is these regressive–transgressive couplets which appear to coincide with mass extinctions. Thus the late Ordovician extinction is followed by extensive black shale deposition in the Llandovery (but was the extinction over by then?). The Frasnian/Fammenian boundary is also associated with anoxic facies (the famous Kellwasser event). Arguably the best documented mass extinction of all (see the work of the students of Erle Kauffman and Malcolm Hart) at the Cenomanian/Turonian boundary is intimately linked to the archetypal oceanic anoxic event. The deep water sections across the Cretaceous-Tertiary are marked by condensed, organic rich clays, again implicating anoxia (although allowance must be made for extra-terrestrial complications!). But what about the Permo-Triassic mass extinction event, the mother of all mass extinctions (as Douglas Erwin termed it in a recent "Online").

The P/T event has received relatively little attention despite a decade of interest in mass extinctions in general. Undoubtedly this is due, at least partly, to the absence of meteorite-impact evidence (despite the claims of a few). A lack of public glamor is probably because no group as well known as the dinosaurs disappeared at this time; the average man-in-the-street does not miss the Permian fusulinids or the productids (although I pine for the goniatites). Probably one of the main reasons for the lack of research, as Erwin suggested, is the rarity of boundary sections available for geologists to study.



Paul B. Wignall is a lecturer in paleontology in the Earth Sciences Department at Leeds University. He received his first degree from Oxford University and his Ph.D. at Birmingham University. The latter involved paleoecological research on the Kimmeridge Clay—the celebrated English Jurassic source rock. This black shale study utilized as many lines of evidence as possible including sedimentological and geochemical data as well as paleontological data. He may have become the first paleoecologist to wield a gamma ray spectrometer. He continued his black shale endeavors during a brief but enjoyable stay at Leicester University. Current investigation includes study of the link between mass extinctions and anoxic events, the position of black shales within a sequence stratigraphic framework and the integration of paleoecological data with geochemical acronyms such as DOP and S/C plots.

In sheer magnitude the P/T event is unrivalled. Raup's classic analysis in 1979 suggested that all but 4% of marine species became extinct. Even conservative estimates consider that around three quarters of species disappeared at this time. Just how sudden the event was is a matter of debate.

As for a causal mechanism there are several lines of evidence. The Late Permian witnessed a remarkably low stand of sea-level with a major regression occurring in the latest Permian. This reduced the shallow marine habitat area and thus, by an extrapolation of the species-area effect to a global scale, the number of marine species. The problem here is distinguishing an effect from a cause. The paucity of marine strata of latest Permian age is bound to give an apparent decline in diversity because of the self-evident, "the less rocks there are to look at the fewer fossils you will find" rule. This causal mechanism also places the mass extinction in the Late Permian. However in those few sections where the latest Permian is preserved there appears to be an upward increase in diversity. Using such sections, Flügel and Reinhardt have shown in the pages of this very journal that reef faunas were diversifying right up to the P/T boundary before their abrupt extinction—a similar pattern occurs in the carbonate shelf faunas of northern Italy.

So, if the marine extinction was sudden and very catastrophic, then what caused it? From detailed facies analysis, undertaken with Tony Hallam, I suspect anoxia in the basal Triassic. This was associated with rapid marine onlap following the latest Permian lowstand. The evidence is there in the form of fine lamination, syngenetic pyrite and typical dysaerobic (including exaerobic) faunas to be seen in many (all?) marine boundary sections in the world. As a mechanism, the spread of anoxia during transgression relies once again on the species-area effect, except this time habitat area is reduced by making shelf seas uninhabitable rather than "losing" them by regression. This idea begs the question of why there is no organic enrichment associated with the basal Triassic anoxia. Perhaps there was little biomass in the oceans at this time, as suggested by carbon isotopic evidence, but now we are into the realms of Strangelove Oceans. . . .

—PAUL B. WIGNALL