MASS EXTINCTIONS AND SEA-LEVEL CHANGES. A. Hallam, School of Earth Sciences, University of Birmingham, Birmingham B15 2TT, UK.

Although the American geologist T.D. Chamberlin was the first to propose, early in the last century, that major faunal changes through time, which provided the basis for stratigraphic correlation, were under the ultimate control of epeirogenic movements of the continents and ocean basins, it was his palaeontological compatriot Norman Newell who began the modern study of mass extinctions. In a series of articles in the 1960s, he proposed a strong relationship between marine mass extinctions and eustatic falls of sea level. Of six major events he recognised, five have become generally accepted as the "big five" mass extinctions at the end of the Ordovician, Permian, Triassic and Cretaceous, and in the late Devonian (Frasnian-Famennian boundary). The causal relationship that Newell proposed involved loss of habitat areas in epicontinental seas, where most at least of the benthic biota are thought to have lived. After the classic publication by Luis Alvarez and colleagues reporting on the discovery of an iridium anomaly at the K-T boundary, interest became concentrated on bolide impact as a causal factor in mass extinctions in general. Insofar as attention was paid to marine regression, a certain amount of scepticism was expressed, for example at the rarity of extinctions that could be related to the evident glacioeustatic regressions of the Tertiary. In 1989 Hallam confirmed Newell's regression hypothesis for at least some major and minor extinction events, but pointed out that the spread of anoxic bottom waters associated with marine transgression, sometimes but not always preceded by a major regression, was also a potent extinction mechanism, presumably because of the severe reduction in viable habitat area. In their 1997 book Hall and Wignall observed that, apart from the K-T boundary, evidence of impact as a causal mechanism for mass extinctions was either weak or non-existent, and even for the K-T boundary there was evidence for major sea-level change that required further evaluation. Of the phenomena apparently related to sea-level change, anoxia associated with eustatic rise seemed to be more important than regression as a correlate of mass extinctions.

A review of the relevant literature coupled with personal fieldwork in some cases suggests that nearly all marine mass extinctions are associated with rapid, probably global, sea-level fluctuations, of which regressive-transgressive couplets are the most common; the most notable exception are the Frasnian-Famennian and end-Palaeocene events. There is no general pattern as to where the extinction occurs within the regression-transgressive cycle. Thus, the late Ordovician extinctions were a double event associated with both regression and transgression. Permian extinctions associated with regression were considerably separated in time from those at the end of the period associated with transgression. The end-Triassic extinctions are more obviously associated with regression than the subsequent transgression and accords well with Newell's hypothesis, but in other respects his hypothesis is not well supported as a model of general validity. Thus, two of his type examples, the late Devonian and end Permian, are now regarded as transgression/sea-level highstand phenomena. While the strong temporal correlation with latest Cretaceous regression and mass extinction holds, it is proving difficult to disentangle the environmental effects of regression from those due to late Maastrichtian climatic cooling and end Cretaceous bolide impact. The most frequent association of marine mass extinctions is with transgression and the spread of anoxic waters into epicontinental seas. This applies to one of the two events near the end of the early Cambian, the second phase of the end Ordovician, the Frasnian-Famennian boundary, the end Devonian, end Permian, early Toarcian and Cenomanian-Turonian boundary. Most workers favour anoxia as the direct kill mechanism.

With regard to the ultimate cause of the sea-level changes, the evidence of tillites provides support for a glacioeustatic origin for the end-Ordovician and end-Devonian events, with sea-level fall being promoted by the build-up of Gondwana ice caps and rise by subsequent melting. For all the other events, however, such evidence is lacking and in some cases is strongly against the kind of climate that would promote the growth of substantial ice-caps. The end-triassic event is especially interesting. The rate of sea-level change across the Triassic-Jurassic boundary in Europe appears to be too rapid to be accounted for by changing oceanic ridge-volume tectonoeustasy. Relatively sharp uplift followed quickly by subsidence can be related to the initiation of breakup of Pangea by tectonial activity recorded on both sides of the present central sector of the Atlantic ocean. This event is associated with extensive flood basalt extrusion and shallow intrusions of dykes and sills, an association that has been related to the existence of a mantle plume. Submarine volcanicity on a massive scale appears to be implicated in the likeliest scenario for the Cenomanian-Turonian boundary, with concomitant phenomena including sea-level rise, a possible runaway greenhouse effect and increased oceanic anoxia. Such a scenario could also be applicable to the end-Permian event, thereby helping to explain substantial extinctions on land as well as in the sea.