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BIOSTRATIGRAPHIC CASE STUDIES OF SIX MAJOR EXTINCTIONS;

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Biostratigraphic case studies of six major extinctions show all are gradual save one, which is a catastrophic extinction of terrestrial origin. These extinctions show a continuum of environmental insults from major to minor. The major causes of these extinctions are positive and negative eustatic sea level changes, temperature, or ecological competition. Extraterrestrial causes should not be posited without positive association with a stratigraphically sharp extinction.

The Cretaceous/Tertiary terrestrial extinction is considerably smaller in percentage of extinction than the marine extinction and is spread over 10 m.y. of the Cretaceous and 1 m.y. of the Tertiary. 60 percent of the 30 dinosaurs in the northern great plains of the U.S. and Canada had become extinct in the 9 m.y. before the late Maastrichtian sea level drop (1). Out of 93 species of vertebrates 1 m.y. before the end of the Cretaceous (as determined by pollen and the iridium layer), 25 percent became extinct during the 2 m.y. straddling the K/T boundary. These include the last 12 genera of dinosaurs, 10 species of mammals, and 2 turtles. This extinction is not sharp, but continuous over the duration of magnetochron 29r, with new mammals migrating into North America as a result of the late Maastrichtian lowered sea level. These new mammals actively competed with the native North American mammals and the herbivorous dinosaurs for food. Very rapid diversification of these immigrants lead to a species by species extinction of both dinosaurs and some native Cretaceous mammals, documented by a carefully dated sequence of localities straddling the K/T boundary. The last dinosaurs in Montana occur in 4 localities in the first 0.2 m.y. of the Paleocene (1,2). The latest dinosaurs in South China occur in rocks conformably overlain by rocks with mammals of North American ancestry no earlier than magnetochron 28r, a full million years after the K/T boundary (3). No other sequences have been investigated in sufficiently close detail to bear on the rapidity or timing of the terrestrial K/T extinction.

The best data on the Permo-Triassic terrestrial extinction are from the Karoo basin of South Africa. This is a series of 6 extinctions in some 8 m.y., recorded in some 2800 meters of sediment (4,5). Precision of dating is enhanced by the high rate of accumulation of these sediments. The faunas are dominated by therapsids. Each of the extinctions occurred relatively rapidly, and was ecologically similar, involving the loss of from 10 to 20 percent of the genera. In each extinction those disappearing include the largest animals, both carnivore and herbivore, and those with the fewest number of advanced mammalian characters. Each extinction was followed by a radiation of the survivors which developed new mammalian characters. The result of sequential extinctions and radiations was the rapid forcing of the mammalization of therapsids. Fully 50 percent of the mammalization of therapsids took place during the 8 m.y. of the Tatarian. Mammalian features developed were those that increased activity and were well suited to the development of homoiothermy, or an independence from low temperatures. Cyclic climatic temperature fluctuations would appear to represent the causes of these multiple extinctions.

Few data are readily available on the timing of the marine Permo-Triassic extinction, due to the very restricted number of sequences of Tatarian marine rocks. Owens (6) reviewed all Permocarboniferous trilobites. Trilobite genera from the beginning to the end of the Carboniferous averaged 10 to 11, rose to 13 in the Early Permian, to 18 in the Kazanian, after the southern hemisphere glaciation was over, but dropped to 6 in the Tatarian with none in the latest Tatarian. This suggests a prolonged extinction of over 8 m.y., with the primary cause the eustatic sea level drop associated with the assembly of Pangaea.

The terminal Ordovician extinction at 438 m.y. is relatively rapid, taking place over about 0.5 m.y. The most significant aspect of this extinction is a eustatic sea level lowering associated with a major episode of glaciation. New data on this extinction is the reduction from 61 genera of trilobites in North America to 14, for a 77 percent extinction. The magnitude of the sea level drop can be inferred from stratigraphic changes in trilobite biofacies on Anticosti Island and the tip of the Gaspe peninsula in Quebec. Richmondian faunas suggest a depth greater than 200 m, while Gamachian terminal Ordovician genera suggest a depth of circa 50 m for a drop of about 150 m. This is compatible with the normal eustatic drop associated with a glaciation (7). The other major extinction in the Ordovician is the mid-Whiterockian extinction with a gradual drop in trilobite genera of 35 percent over a 5 m.y. period starting at 73 genera at 484 m.y., remaining low in diversity at 47 to 50 genera until 471 m.y., before rising to a peak of 107 trilobite genera at 465 m.y. This last is 27 m.y. before the terminus of the Ordovician, suggesting Raup and Sepkoski's (8) cyclic extinction hypothesis is not operative during the Ordovician. This 11 m.y. interval of relatively low diversity is associated with the major withdrawal of the sea from the craton that separates the Sauk and Tippecanoe sequences.

Another Ordovician extinction present over 10 percent of the North American craton occurs at 454 m.y. in the form of a catastrophic extinction due to a volcanic eruption which blanketed the U.S. east of the Transcontinental Arch. The volume of this eruption, the Deicke K-Bentonite, is estimated to be about 1000 cubic km (9). This ash is considered to be the Blackriver/Trenton boundary, the trilobite extinction is from 86 to 68 genera, 21 percent. This is the only other sizeable extinction in the Ordovician.

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