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LIMITATIONS ON K-T MASS EXTINCTION THEORIES BASED UPON THE VERTEBRATE RECORD;

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Theories of extinction are only as good as the patterns of extinction that they purport to explain. Often such patterns are ignored. For the terminal Cretaceous events, different groups of organisms in different environments show different patterns of extinction that to date cannot be explained by a single causal mechanism.

Several patterns of extinction (and/or preservational bias) can be observed for the various groups of vertebrates from the uppermost Cretaceous Hell Creek Formation and lower Paleocene Tullock Formation in eastern Montana. This remains the only region in the world so far studied that preserves an adequate record of the non-marine K-T extinction patterns. Although the Bug Creek channel sequences provide fascinating clues to extinction patterns, they are also stratigraphically ambiguous. Even if the sequence is ignored and one relies solely on stratigraphically straightforward settings, as we do here, one still obtains data that are quite informative and that set limitations on extinction scenarios.

The taxonomic level at which one chooses to calculate the percentage of survivals (or extinctions) will have an effect upon one's perception of faunal turnover. The biologically least ambiguous level is that of the species. Higher taxonomic levels for the same groups may sometimes over or underestimate the amount of turnover. Our calculations use the species-level as the O.T.U., unless otherwise specified.

In addition to the better known mammals (about 27 species) (ref.1) and better publicized dinosaurs (about 20 species), there are almost 60 additional species of reptiles, birds, amphibians, and fish (refs. 2,3) in the Hell Creek Formation. Simple arithmetic suggests only 33% survival (35 of 107) of these vertebrates from the Hell Creek Fm. into the Tullock Fm. A more critical examination of the data shows that almost all Hell Creek species not found in the Tullock are represented in one of the following categories; 1) extremely rare forms, including very late survivors of archaic groups, 2) elasmobranch fish and others that may have lived in brackish water or lived in marine waters for part of their life cycle, 3) strictly terrestrial forms such as lizards and the tortoise-like *Basilemys*, 4) taxa, especially mammals, that underwent rapid speciation during the transition and although not represented by the same species in both formations, have lineages found in both, and 5) taxa that although not

known or rare in the Tullock, are found elsewhere in the world in Paleocene or younger faunas. Each of the 5 categories is largely the result of one or more of the following biases: taphonomy (category 1), ecological differences (2 and 3), taxonomic artifact (4), or paleogeography (5).

The two most important factors appear to be the possible taphonomic biases listed under category 1 and the taxonomic artifacts of category 4. Some 67% (22 of 33) of the non-dinosaurian (similar data not available for dinosaurs) Hell Creek taxa not found in the Tullock are those known from fewer than 10 out of over 10^5 specimens in UCMP collections. Most of these are fish, lizards, and mammals. Of the taxonomic groups in this sample of 107 species, only the mammals show a very high appearance/speciation rate through the K-T transition. Of the 27 Hell Creek mammal species, 11-13 have some close relative in the Tullock, however, by strict adherence to species-level groupings through the K-T transition one would calculate a survival rate approaching zero for mammals. This taxonomic artifact can be lessened by using the mammal species-lineages rather than simply the species names of the mammals. If one excludes the extremely rare taxa and uses mammal species-lineages, one arrives at a percent survival of 72% (47 of 65) for non-dinosaurian taxa and 55% (47 of 85) if dinosaurs are included (N.B.: Some of these dinosaurs are very rare).

With the exception of fish, lizards, dinosaurs, and marsupials, taxa common in the Hell Creek Fm. remain common in the Tullock. Gars, sturgeons, salamanders, aquatic turtles, crocodiles, and multituberculates are abundant in both formations; champsosaurs become much more common after the end of the Cretaceous.

The extinction patterns among the vertebrates do not appear to be attributable to any single cause, catastrophic or otherwise. The earliest Paleocene fauna can be understood as a Late Cretaceous fauna simply altered by withdrawal of the Western Interior Sea and by the formation of extensive swamps that replaced well-drained terrestrial environments.

(1) Archibald, J.D. (1982) U.C. Publs. Geol. Sci., 122, p. 1-286.
(2) Bryant, L.J. (in press) U.C. Publs. Geol. Sci.
(3) Hutchison, J.H., and Archibald, J.D. (1986) Palaeogeog., Palaeoclimat., Palaeoecol., 55, p. 1-22.