

Reports

Mid-Oligocene Extinction Event in North American Land Mammals

Abstract. Interest in extraterrestrial causes for the apparent 26- to 32-million-year periodicity of mass extinctions has focused on the terminal Eocene event and older events, although there is now evidence of a mid-Oligocene event near the early/late Oligocene boundary, or about 32.4 million years ago. An abrupt (200,000 years or less) mid-Oligocene extinction event appears in the record of North American land mammals, which results in the selective disappearance of archaic members of the fauna and later diversification of other taxa. The selective nature of the extinctions suggests climatic and ecological causes rather than an extraterrestrial catastrophe. Increased mid-Oligocene glaciation, worldwide cooling, a major regression event, and abrupt changes in the flora are probably the immediate causes, and these may have resulted from changes in global oceanic circulation.

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The changes in the North American mammal fauna at the boundary between the Chadronian and Orellan land mammal ages (1) have attracted relatively little attention, although the extinction of

the titanotheres at this time has provoked speculation (2) about causes of the changes. Paleomagnetic data (3-5) now make it possible to correlate the Oligocene land mammal record with the worldwide climatic record.

The correlation of terrestrial magnetostratigraphy with the magnetic polarity time scale (4) suggests that the Chadronian-Orellan boundary occurs about 32.4

million years ago. Correlation of the planktonic zonation (6) with the polarity time scale suggests that the Chadronian-Orellan boundary occurs at the top of planktonic foraminiferal zone P20 and near the middle of calcareous nannofossil zones CP18 and NP23. Terrestrial magnetobiostratigraphic studies (3) have established temporal ranges of mid-Oligocene North American land mammals indicating that a number of mammalian families (Fig. 1) last appeared within a short span of stratigraphic section near the end of the Chadronian. These families included not only the titanotheres, but also the primitive camel-like oromerycids, the mole-like epicotheres, the pantolestids, and the primitive paramyid and cylindrodont rodents. In the early Orellan, most of these taxa were not replaced. However, there was some diversification of eumyine cricetid rodents, and the high-crowned leptauchenine oreodonts made their first appearance at this time. The oreodont *Miniochoerus* (3, 7) shows rapid dwarfing across the Chadronian-Orellan boundary, resulting in a 36 percent reduction in size. Speciation in the deer-like *Leptomeryx* and the camel *Poebrotherium* also occurred near this boundary. In most other respects, however, the typical Orellan fauna was quite similar to the late Chadronian fauna.

Magnetostratigraphy has also made it possible to estimate the rate of these changes. Correlation of the late Chadronian normal polarity event with chron C12 of the magnetic polarity time scale (6), and the early Orellan normal event with chron C11 (4, 5) indicates that the Chadronian-Orellan boundary is contained within chron C11R. Calculation of average sedimentation rate between paleomagnetic time planes (Fig. 1) suggests a span of no more than 200,000 years for the Chadronian-Orellan extinction event. This event might be even shorter in duration if normal range extensions due to improved sampling are taken into account. Such an abrupt transition has not been suspected, since a complete, thick sequence spanning this time interval is not preserved in the classic sections of the Big Badlands of South Dakota (2) or equivalent rocks of Nebraska (8). Much higher resolution of this event can be seen in sections near Lusk (3, 9) and Douglas (3), Wyoming (Fig. 1).

Although this faunal transition is relatively rapid, it is not catastrophic. Extinction at the Chadronian-Orellan boundary was selective, occurring in archaic groups that were primarily relicts from the Eocene. Most of the other changes (dwarfing and speciation) are

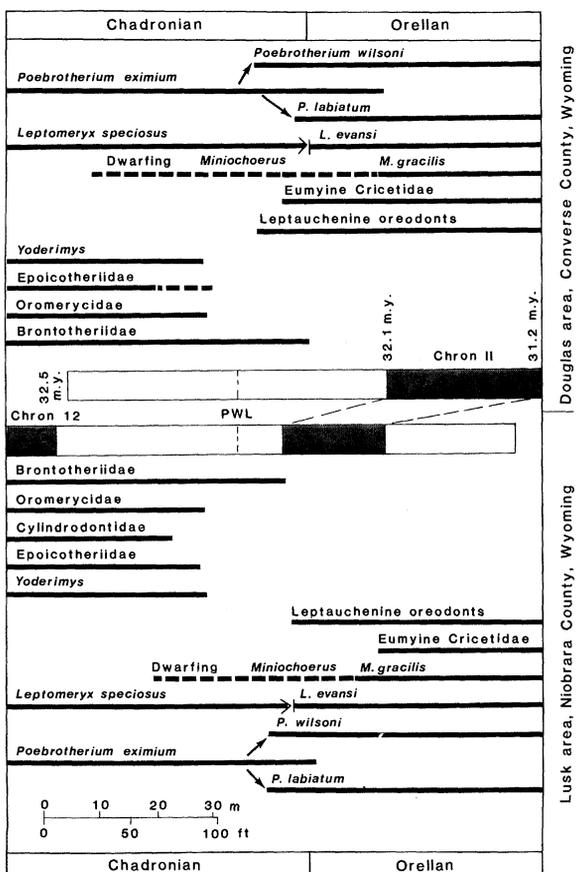


Fig. 1. Stratigraphic ranges of mammals most strongly affected by the mid-Oligocene event in two areas in Wyoming: Douglas, Converse County, and Lusk, Niobrara County. Biostratigraphy and magnetostratigraphy are taken from (3). Age of magnetic polarity event boundaries in millions of years are based on (6).

drawn out over the entire transition and do not suggest geologically instantaneous, catastrophic causes. The lack of change in the bulk of the fauna also argues against indiscriminate, periodic extraterrestrial extinction events (10). The Chadronian-Orellan transition strongly suggests that there was a major ecological and climatic change, since similar changes in the reptilian fauna (11), the vegetation (12), and the soil horizons (13) have been reported at this time.

A major mid-Oligocene cooling event, as suggested by the benthic foraminiferal $\delta^{18}\text{O}$ record (14–16), and circulation event, as suggested by the planktonic foraminiferal $\delta^{13}\text{C}$ record (14), are known to have occurred. The largest regression in the Tertiary is reported (15, 17) from the mid-Oligocene and apparently was caused by a glacio-eustatic fall in sea level (15). Evidence from planktonic microfossils (15) suggests that this regression began at the top of planktonic foraminiferal zone P20 or the base of zone P21a. Cooler water forms of planktonic foraminifera (18) increasingly dominate in the mid-Oligocene. *Braarudosphaera*, a coccolithophorid that is associated with crises, is common in the mid-Oligocene (19).

The combined faunal and isotopic evidence together have been interpreted as indicating an increase in Antarctic ice volume and concomitant global cooling in the mid-Oligocene (15, 20). This might have been caused by increased development of the circum-Antarctic current and resulting refrigeration of the Antarctic continent due to circumpolar deepwater circulation between Tasmania and Antarctica (20). Better knowledge of the precise sequence and timing of these events worldwide will allow a more definite chain of cause and effect to be reconstructed.

References and Notes

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Soil Radon and Elemental Mercury Distribution and Relation to Magmatic Resurgence at Long Valley Caldera

Abstract. *The response of a large geothermal system to magmatic resurgence was analyzed by a survey of soil gas radon and elemental mercury at 600 sites in the silicic Long Valley Caldera, California. The broad geochemical anomaly over the caldera has superimposed on it a small zone of pronounced radon enrichment and mercury depletion coincident with the surface projection of a postulated dike of rising magma. Soil gas geochemistry studies can complement traditional geophysical and geodetic methods in the evaluation of potential volcanic eruption hazards.*

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Geochemical monitoring of volcanic gases from high-temperature fumaroles (1) and from soil gas (2) has demonstrated that changes in gas ratios or flux are sometimes related to eruptions or seismic activity at volcanoes. In the study reported here I sought to identify geochemical changes caused by magmatic resurgence (3) at Long Valley Caldera, California. This silicic caldera formed 700,000 years ago during the explosive eruption of the Bishop Tuff (500 km³) (4). It has since been the site of smaller eruptions, including some as recent as 550 years ago (5). Increases in seismicity, uplift, and ground deformation beginning in 1978 led the U.S. Geological Survey to issue a warning of potential volcanic eruption hazard in 1982 (6).

In previous studies (2, 6, 7), investigators identified a widespread Hg⁰ anomaly associated with the caldera geothermal system and a new Hg⁰ anomaly in the Inyo craters zone after magmatic resurgence commenced. Radon (9), hydrogen (2), and helium (2, 10) have also been studied in Long Valley since 1978.

This study included approximately 600 measurements of Rn in soil gas and Hg⁰ on soil particles from the caldera and the

surrounding area. These two elements were studied because, although both are heavy, they have contrasting geochemical characteristics. Radon is inert and has been detected in geothermal steam (11) and on faults over active volcanoes (12). Because it is radioactive (half-life, 3.8 days), it can be detected at very small concentrations. Its movement is probably promoted by convection set up by high geothermal gradients. Mercury is reactive, important in geothermal systems (13), and accumulates on the clay-size fraction of soils. Anomalous concentrations thus indicate zones in which vertical convective heat flow is (or has been) present. Differences in Rn and Hg⁰ relations can thus distinguish zones of current gas flux from fossil signatures.

Radon measurements were made with the Terradex Track Etch system (14), which is designed to give integrated readings that minimize the effects of diurnal and barometric pressure. Detector cups were buried at a depth of 40 cm for approximately 30 days before being recovered for analysis by the manufacturer. Mercury was detected by using the Jerome Instrument 301 Au-film Hg⁰ detector (15) on air-dried soil samples (<80 mesh fraction) from the base of Rn detector holes.

Sample sites (Fig. 1) were generally near roads and trails and were chosen after careful consideration of the local geology and structure because experience at other active volcanoes (2, 12) has demonstrated that they may exert a