PALEOCEANOGRAPHY

Did a Blast of Sea-Floor Gas Usher in a New Age?

About 55 million years ago, the environment went topsy-turvy and evolution took a leap. A host of modern mammals—from primates to rodents—abruptly appeared in the fossil record of North America. At the same geologic moment, near the end of the Paleocene epoch, tiny, shelled creatures called foraminifera suddenly went extinct at the bottom of the sea. And various temperature indicators record a sudden burst of warming on both sea and land, while isotopic signals in forams and mammal teeth suggest a sharp shift in the global carbon cycle.

Now, a new mathematical model points to a single explanation for all these events: a giant release of methane gas from the ocean. In the March *Geology*, paleoceanographer Gerald Dickens, water chemist Maria Castillo, and geochemist James Walker of the University of Michigan use a model of the global carbon cycle to show how a gradually warming ocean might have altered its circulation and triggered a 10,000-year-long burst of methane from the sea floor. Because methane and its oxidation product, carbon dioxide, are greenhouse gases, such a release would have turned the ocean warming into a pulse of greenhouse heating that helped alter the course of evolution on land.

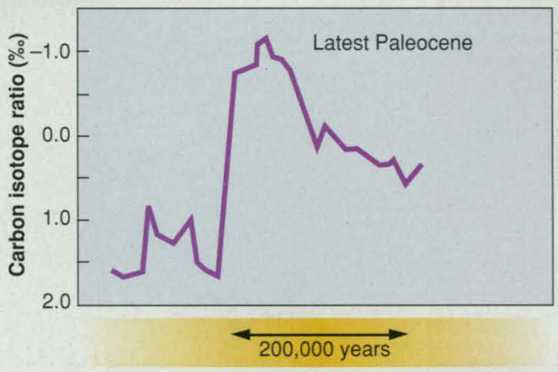
PHOTOS BY E. THOMAS/WESLEYAN UNIVERSITY

Although the Michigan gas-blast calculations don't prove this scenario, they "confirm what a lot of us had been suspecting," says paleoceanographer James Zachos of the University of California, Santa Cruz. "That's the first time someone has actually done a numerical analysis [of the methane hypothesis]. The results match what we see in the sedimentary record." The new plausibility of the methane mechanism will bolster efforts to pin down what happened in the sea 55 million years ago and spur pursuit of other possible gas bursts, says Zachos.

For several years, paleoceanographers have suspected that a belch of climate-altering methane from the oceans could unite their pictures of what happened on land and in the sea. In the ocean, sea-floor forams suffered a mass dying near the end of the Paleocene, and researchers found a striking coincidence between the extinctions and a warming of bottom waters by several degrees, as indicated by a shift in the oxygen-isotopic composition of foram shells. They suggested that this abrupt shift was due to a change in ocean circulation in which warm equatorial waters grew salty and dense enough to sink to the bottom and displace the existing cold, polar bottom water. In response, many of the deep-dwelling forams just winked out, researchers concluded.

On land, temperature indicators such as oxygen isotopes in surface-dwelling forams in the sea and changing leaf shape on land implied a burst of warming. Paleontologists suspect that it was this warming that spurred the explosion of North American mammals, perhaps by opening up a high-latitude land route to allow immigration from another continent (*Science*, 18 September 1992, p. 1622).

The thread linking land and ocean was a spike in the relative abundance of the lighter carbon isotope, carbon-12. In the ocean, researchers have detected the spike in the skeletons of the surviving forams and, on land, in fossil mammal teeth dating from the precise geologic moment when the new mammals appeared. Nothing but a burst of methane, it seemed, was able to produce such a large and abrupt isotopic shift. "If you go through the usual suspects, none of them works," says paleoceanographer Ellen Thomas of Wesleyan University in Middletown, Connecticut. Erosion of carbonate rocks on land would be too slow, for example, and the carbon dioxide of volcanoes is not light enough.



DICKENS ET AL./GEOLOGY

Gas blast. Methane may explain why forams died and isotopes spiked.

The lightest carbon on Earth is in methane produced by bacteria in low-oxygen environments, such as bogs and sea-floor muds. And some sea-floor methane forms a vast reservoir that—in theory—could be released catastrophically, because it is frozen into buried water ice that traps methane molecules within the cages of its crystalline structure. In this hydrate form, 15 trillion tons of methane are thought to lie buried beneath the sea floor today. Paleoceanographers realized that the sudden switch to warm bottom waters like those of the Paleocene might melt enough hydrate to release methane to the ocean and atmosphere. That, in turn, could create the carbon-isotopic spikes, as well as the burst of greenhouse warming.

To see if such arguments held up quantitatively, Dickens, Castillo, and Walker adopted a mathematical model developed by Walker and James Kasting of Pennsylvania State University to calculate the fate of anthropogenic carbon dioxide. Given the geologically instantaneous transformation of methane into carbon dioxide, the Michigan group introduced an extra 160 cubic kilometers of carbon dioxide per year into the model during a period of 10,000 years, which was the rise time of the isotopic spike. They then watched for a million years as light carbon built up in the model's atmosphere, mixed into the oceans, and reacted with sediments and with rock on land.

In the end, the model behaved much as the world did near the end of the Paleocene. Assuming that Paleocene hydrates were as voluminous as today's, release of just 8% of the total—less than the bottom-water warming is estimated to have caused—was enough to lighten the ratio of carbon isotopes in the ocean and atmosphere by 2.3 parts per thousand, compared with the 2.5-parts-per-thousand change recorded by forams. And the isotope signal in the model slowly faded over 200,000 years, just as observed in the rock record, presumably as dissolution of sea-floor carbonate and weathering of rocks on land removed the light carbon dioxide. The model's atmospheric carbon dioxide peaked at a concentration that would have warmed the surface by 2°C, a good part of the observed 4°C warming.

Given the model's performance, "I really like the idea," says Thomas, which leads her to wonder if there were other gas bursts. If ocean circulation were poised delicately enough to switch once, says Thomas, it might have switched many times. The subsequent Eocene epoch was exceptionally warm and supposedly climatically tranquil, but the ocean record of it is sketchy. The primates and sea-floor forams, having already gone through a sudden warming, might not have reacted, but smaller gas bursts might have played other mischief. Thomas and others will be seeking the signs.

–Richard A. Kerr