Nonmarine Iridium Anomaly Linked to Extinctions

Some researchers have suggested that an asteroid or comet impact caused mass extinctions that included the dinosaurs. They base this extraterrestrial hypothesis on the discovery of exceptionally high concentrations of the element iridium in ocean sediments laid down at the time of the extinctions about 65 million years ago. Doubters have offered alternative, terrestrial explanations for the iridium anomalies (*Science*, 31 October 1980, p. 514), but the announcement at the recent American Geophysical Union meeting in Baltimore of an iridium anomaly in freshwater sediments has undercut those already shaky counterarguments.

Charles Orth of Los Alamos National Laboratory reported that he and a team of nuclear chemists, geologists, and paleontologists* found a narrow zone of high iridium concentrations in sediments deposited in northeast New Mexico by freshwater streams and swamps. Using nuclear activation analysis to measure iridium and pollen analyses to detect plant extinctions, they zeroed in on the anomaly and the time of the extinctions by taking samples spaced progressively closer from a rock core drilled in the Raton Basin. They found that plant extinctions associated with the extinction of the dinosaurs occurred between two thin layers of coal separated by 1 meter of mudstone.

The iridium anomaly included a 5-centimeter layer spanning the boundary between the mudstone layer and the upper coal layer. The concentration of iridium in the anomalous layer is 4000 parts per trillion, which is about 200 times higher than in the rock above and below it. The total iridium deposited in the layer is about 30 nanograms per square centimeter, Orth says, which is in the lower range of anomalies elsewhere. The only other example of a nonmarine iridium anomaly reported to date, one in Montana mentioned by Luis Alvarez of Lawrence Berkeley Laboratory and his colleagues in a letter to *Science* (13 February 1981, p. 654), has been retracted. A technician's jewelry contaminated the Montana samples but no others.

The New Mexico iridium anomaly seems to greatly weaken if not demolish current arguments that a large extraterrestrial object need not have hit Earth at the time of the extinctions. More mundane, noncatastrophic processes that might have deposited iridium on the ocean floor do not operate well in streams and swamps. For example, strong ocean bottom currents stirred by climatic changes associated with the extinctions might have winnowed away lighter sediment particles, leaving heavier particles concentrated in a layer. Among those particles may have been the cosmic dust and micrometeorites that steadily rain onto Earth. But nothing like that winnowing is likely to have happened in a stream. The same problem crops up if changes in the rate of sedimentation or a surge in the deposition of organic matter is invoked. More viable alternatives to the extraterrestrial hypothesis will require new thinking on the part of geochemists, cosmochemists, and sedimentologists.

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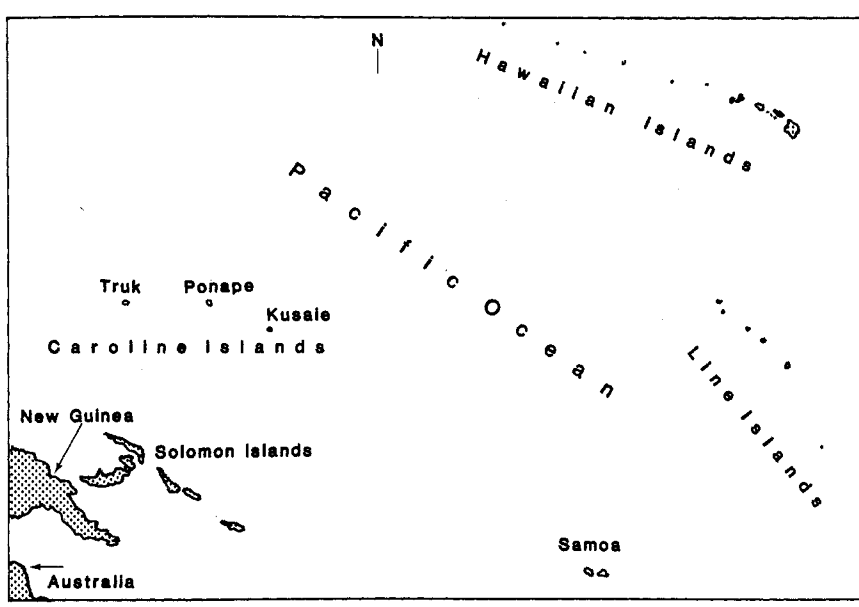
A Hot Spot Found, Another Discarded

The number of isolated, persistent, nearly stationary centers of volcanic activity exceeds 100 by some counts, but those widely regarded as classical hot spots, such as the island of Hawaii, are still few. At the American Geophysical Union meeting, researchers argued against one possible hot spot and tentatively confirmed the existence of another.

The loser was the Line Islands hot spot, postulated to lie south of Hawaii. Like the Hawaiian chain, the volcanic Line Islands (including Christmas Island) lie on a slightly curved line, as they must if they originated at a hot spot. Lava piling up at a hot spot will form a ridge or a chain of islands and seamounts as the ocean crustal plate moves steadily over the hot spot. But the Line Islands fail a second required test. If a hot spot trails a linear chain of islands as the plate moves, the closer an island is to the hot spot, the younger the island should be.

Earlier studies have shown that a suspiciously long portion of the chain experienced active volcanism simultaneously rather than sequentially. Janet Haggerty and Seymour Schlanger of the University of Hawaii and I. Premoli-Silva of the University of Milan extended the length of that portion when they dredged and dated fossils associated with volcanic rocks near Caroline Island. They concluded that volcanoes spewed lava simultaneously along 2500 kilometers of the chain's 4200-kilometer length more than 70 million years ago.

In addition, William Sager of the University of Hawaii reported that measurements of the remanent magnetism of Line Islands rocks, which is a trace of the earth's magnetic field



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frozen into the rock when it formed from lava, show that much of the chain did not form at a single latitude, as required by the hot-spot hypothesis. Although some researchers suggest that the Line Islands might have been produced by two hot spots, it appears that these islands might alternatively be called the product of a "hot line" rather than a hot spot. A rising plume of mantle material could still have supplied the magma to build the Line Islands, as plumes are thought to do beneath classic hot spots, but the plume would have melted through the crust along a line of weakness rather than at a single spot.

In contrast, the Caroline Islands, located north of the Solomon Islands, have all the characteristics of a classic hot spot trace, according to Barbara Keating and her colleagues at the University of Hawaii. The island ages fall in the proper order, from Truk (12 to 14 million years), to Ponape (8 million years), to Kusaie (4 million years). Those ages, the spacing of the islands, and the orientation of the chain all fit those predicted from studies of the passage of the same Pacific plate over the Hawaiian hot spot. Paleomagnetic studies indicate that all three islands formed at a latitude of about 2°. And the chemical composition of rocks from all three islands suggests a similar source for the lavas.

Although the suspected hot spot has not created an island for 4 million years, the Hawaii researchers believe that they can locate it. If the motion of the plate deduced from the ages and spacing of the islands is carried forward to the present, the hot spot now lies at 4.8°N, 165.7°E, within 2° latitude of the site predicted by paleomagnetic studies. That area also has a broad bulge in the ocean bottom and indications of unusually high earthquake activity, both characteristics of hot spots. One topographic survey even revealed a submarine volcano at least 1300 meters high near the site.

An 1899 account of a Ponapean legend provides less concrete but intriguing evidence. It recounts a 4-day open-ocean voyage south and east of Ponape. The trip came to an abrupt end when the islanders encountered fire in the sea and sky, an apparent reference to a submarine eruption from the suspected hot spot.

Are Ocean Islands Recycled Ocean Crust?

Where do ocean islands come from? From the mantle more than 100 kilometers below the surface, but no one knows exactly what part of the mantle. Geochemists have known that the mantle must be divided into at least two separate compartments containing different kinds of rock, one to form islands and one to form new ocean crust at midocean ridges. There were some loose ends, but it seemed that all oceanic rocks could be made by mixing magma from the melting of two kinds of mantle rocks.

Now, as geochemists discover a disconcerting variety of rocks on ocean islands, researchers are reviving the old idea that a third magma source—old ocean crust—is needed. Some exceptional rocks from Samoa prompted William White and Albrecht Hofmann of the Max Planck Institute for Chemistry in Mainz to propose their own model of how old ocean crust that plunges into the mantle at deep ocean trenches might pop up billions of years later as ocean island lava.

Samoan rocks are among an increasing number of ocean island rocks with renegade geochemical properties. For example, if the isotopic properties of neodymium are plotted against those of strontium for a variety of rocks a straight line usually results. Because these isotopes act as indicators of the chemical composition of the rock's source in the mantle, geochemists took the straight-line relation as an indication of the mixing of two mantle components from either end of the line to produce the rocks that fell in between. White and Hofmann found that Samoan rocks plotted well off the line, indicating that at least three components are involved in making ocean rocks.

A good candidate for the third component is recycled ocean crust, Hofmann and White say, because its chemical and isotopic properties best fit those assumed for the source of ocean island lavas. Those properties are first determined when part of the mantle melts to form the magma that becomes the ocean crust. That crust is altered when seawater circulates through it and when, accompanied by sediments, it dives back into the hot, high-pressure mantle. Being denser under mantle conditions than the surrounding rock, the crust continues to sink, retaining enough of the characteristics of crust, sediment, and seawater to account for the peculiarities of oceanic island rocks, according to the model.

Piling up at some depth appropriate to its density, the crust would slowly warm itself from the radioactive decay of elements that were enriched in it when it first separated from the mantle. Once hot enough, perhaps after 1 billion years or more, a blob of crust would begin to rise, partially melt, form a hot spot, and begin to produce ocean islands. Jason Morgan of Princeton University suggested the existence of such rising plumes more than 10 years ago.

American Samoa

The Hofmann and White model, although interesting, has a few problems, according to some observers. How could the crust keep enough water as it passed into the mantle to contain as much water as ocean island rocks do? What prevents the rising blobs from mixing too much with the surrounding mantle? To avoid some of these problems, Don Anderson of Caltech, in his model, recycles the crust through a shallow route. Geoffrey Davies of Washington University creates blobs of various shapes, sizes, and compositions from recycled crust and other sources. These blobs then circulate throughout the mantle. Lacking more restrictive data, geochemists cannot confidently choose between the competing models, but ocean crust recycling now seems to be a popular part of models of ocean island formation.

—***Richard A. Kerr***—