Pipsqueak. Large igneous provinces can boast a million times the lava produced by Iceland's 1783 Laki eruption (buses, *left*, for scale).

GEOCHEMISTRY

Humongous Eruptions Linked to Dramatic Environmental Changes

Researchers looking for the cause of big, catastrophic changes on planet Earth have fingered a new one: so-called flood basalt eruptions, or large igneous provinces (LIPs) eruptions. These are no Mount St. Helenses or even Krakataus, which cooled the planet a degree or so and painted pretty sunsets for a couple of years. No, a single LIP eruption can spew 100 times the magma of anything seen in historical times. The 1000 such eruptions that can follow the first could build a lava pile of millions of cubic kilometers. Such massive volcanic activity seems to have dramatically altered the atmosphere and oceans for hundreds of thousands of years 94 million years ago and again 56 million years ago, according to two new studies.

The newly strengthened link between megaeruptions and major environmental events comes in studies that draw on a single geologic record containing two signatures: that of a LIP eruption and another of a geologically abrupt environmental change. On page 587, geochronologist Michael Storey of Roskilde University in Denmark and colleagues use precise rock dating to tie the outpourings of a LIP—whose remains now span the North Atlantic from Greenland to Great Britain—to the sudden 5°C warming 56 million years ago known as the Paleocene-Eocene thermal maximum, or PETM (*Science*, 19 November 1999, p. 1465).

Scientists have long thought that the gigaton burst of greenhouse gas—carbon dioxide or methane—that marked the beginning of the PETM must be linked to the 5 million to 10 million cubic kilometers of erupted North Atlantic magma, if only because they happened at about the same time. But having to date the two events in different records using different techniques made the case less than convincing. So Storey and his colleagues dated more rocks from the LIP using the argon-argon technique based on the radioactive decay of potassium-40. Combined with previously published data, the dating places one of the largest surges of magma of the past quarter-billion years at 56.1 ± 0.5 million years ago.

The team also applied argon-argon dating to volcanic ash buried in marine sediments southwest of Great Britain that also contain a record of the PETM. That ash layer had been linked to a LIP ash deposit in East Greenland with a similar age, but the researchers beat down the uncertainty by making a total of 50 age measurements on the two ashes. Using additional published dating of the sediment between the ash layer and the start of the PETM, Storey and his colleagues put the beginning of the PETM at 55.6 million years ago.

The new dating thus places the most dramatic warming of its kind just within the uncertainty of the beginning of one of the largest volcanic outpourings ever. "I think that the dating is quite good," says Paul Renne of the Berkeley Geochronology Center in California. It "certainly provides strong linkage between the PETM and the [LIP]."

Another study has strengthened the linkage between massive volcanism in the Caribbean and an abrupt transformation of the oceans 94 million years ago, known as oceanic anoxic event 2 (OAE2). OAEs were a half-dozen episodes in the warm mid-Cretaceous period 120 million to 80 million years ago when ocean sediments accumulated with so much organic matter that the sediments turned black. Something shifted ocean conditions to produce these "black shale" sediments, perhaps by eliminating oxygen from the deep sea. The leading candidate for a trigger is large volcanic eruptions.

OAE2, the archetypal OAE event, had been linked to the massive Caribbean LIP through dating, but geochemist Junichiro Kuroda of the Institute for Research on Earth Evolution in Yokosuka, Japan, and colleagues took a different approach. They harked back to the search in the 1980s for markers of a large impact buried along with the remains of dinosaurs and other life snuffed out 65 million years ago. Instead of the element iridium brought in by an impacting asteroid, they looked at sedimentary lead, a potential marker of a rock's source. They traced lead's isotopic composition across the onset of OAE2 at an outcrop in Italy.

In a few centimeters of sediment leading up to the start of OAE2 and beyond, the relative proportion of lead-208 dropped precipitously, they found. "The way it moves is difficult to explain without a volcano" contributing its distinctive mix of lead isotopes, says geochemist Catherine Chauvel of the University of Grenoble, France. In addition, the new lead-isotope composition bears a particular resemblance to that of the Caribbean LIP.

So, rare and extraordinary volcanic eruptions coincide in time with rare and exceptional environmental changes, strongly linking eruptive cause to environmental effect. However, that link isn't yet clarifying just how LIPs wreak their havoc. For that, researchers will need more timings on more of the cascading effects of humongous eruptions.

–RICHARD A. KERR

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