Eruptions Spark Explosions of Life

Despite their reputation as deadly scourges, giant volcanic eruptions may have profoundly benefited life on Earth by triggering two of the greatest biological revolutions in the planet's history.

Massive outpourings of lava, particularly those in the deep ocean, spurred bursts of evolution early in the Paleozoic era, about 550 million years ago, and in the middle of the Mesozoic era, around 200 million years ago, claims biologist Geerat J. Vermeij of the University of California, Davis. In support of this controversial hypothesis, Vermeij notes that the biological changes took place while extensive undersea eruptions were creating new ocean basins and ripping apart oversized continents.

Time	Period	Era
540	Cambrian	Paleozoic
510	Ordovician	
439	Silurian	
409	Devonian	
363	Carboniferous	
290	Permian	
245	Triassic	Mesozoic
208	Jurassic	
146	Cretaceous	
65	Tertiary	Cenozoic

Biological upheavals marked the early Paleozoic and middle Mesozoic eras (in yellow).

"We have simply got to explain the timing, and to me the coincidence between some of these huge volcanic events and the biological revolutions is just too weird. There has to be a connection," Vermeij told SCIENCE NEWS.

The early Paleozoic revolution produced the first predators, burrowing animals, and creatures able to harvest minerals to form skeletons. Starting in late Precambrian time, this biological blast extended into the middle Ordovician period. The Mesozoic revolution ran from the late Triassic period through the late Cretaceous. It brought a proliferation of marine creatures, including important new types of plankton that could grow mineralized shells. On land, social insects and flowering plants began to conquer the continents.

To explain the coincidence between geologic and biological events, Vermeij suggests that the submarine eruptions loosened the restrictions on organisms living at the time by increasing the availability of energy and nutrients. Using economics as an analogy, he suggests that the volcanic eruptions enhanced the supply of raw materials in the environment and provided organisms with easier access to such commodities. Vermeij discussed his hypothesis last month in the spring issue of PALEOBIOLOGY.

Undersea eruptions aided life on Earth by releasing massive amounts of carbon dioxide, which produced periods of greenhouse warming, claims Vermeij. In the warmer climates, biologically important chemical reactions could proceed much more readily, enabling organisms to boost their metabolisms. Warmer weather and increased amounts of carbon dioxide in the atmosphere also enhanced erosion on the continents, thereby freeing important nutrients from rocks.

The volcanic activity altered the landscape as well. Eruptions raised sea levels by producing hot new ocean crust that sat higher than the old ocean floor. As the swollen oceans flooded continental coastlines, the area of shallow seas grew markedly. These regions, with their abundant nutrients and sunlit waters, would have provided fertile new habitats for ocean organisms.

The question of what sparks biological revolutions has long captivated paleontologists and evolutionary theorists. Some researchers have favored so-called intrinsic explanations, which link evolutionary bursts to genetic or biochemical innovations such as the origin of seed-bearing plants. Other scientists tie life revolutions to external causes, such as chemical changes in the ocean, climate changes, or mass extinctions.

In Vermeij's theory, external factors explain only part of the story. Ecological forces, such as competition and predation among organisms, also play an important role in evolution. "The timing and rates of evolution are dictated by extrinsic factors, but the directions of evolution are largely determined by what other organisms are doing," he says.

David Jablonski of the University of Chicago says that Vermeij offers a number of tests for assessing the new hypothesis. He cautions, however, that paleontologists always face a difficult task when trying to document whether one event caused another.

Paleontologist Douglas Erwin of the National Museum of Natural History in Washington, D.C., questions the link between volcanic eruptions and biological revolutions. "I don't think the timing [of the two] is really as close as it would need to be," says Erwin.

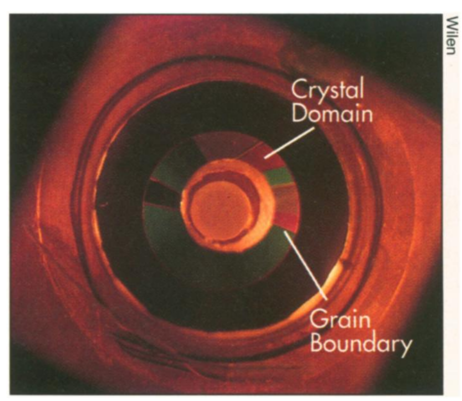
But he lauds Vermeij for bringing economic arguments to evolutionary studies. Although scientists since Darwin have linked the two subjects, Vermeij has done so more completely than others. "I think economics are enormously fruitful and tremendously underutilized," says Erwin. "I've told students that the two courses they should take outside paleontology are Shakespeare and economics." — *R. Monastersky*

Viewing frost heave on a microscopic scale

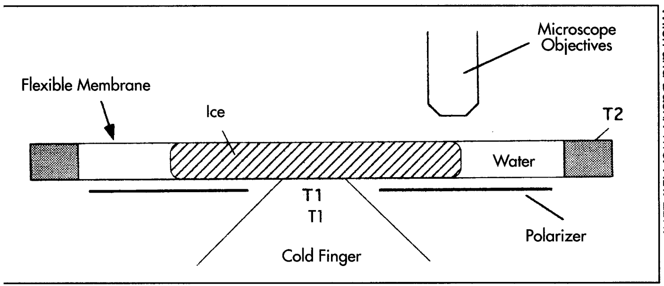
In cold climates, spring often brings city streets strewn with potholes, highway surfaces punctuated by unexpected bumps, fields overgrown with freshly exposed boulders, and soils that feel spongy and soft.

These effects all result from a common phenomenon known as frost heave. It occurs when water-saturated soil freezes, pushing the ground up.

But this upward movement isn't due solely to the expansion that occurs when water turns to ice. A number of other factors come into play, including the existence of unfrozen water at temperatures below water's normal freezing point; this superchilled water tends to dribble through soil toward layers having a lower temperature, where it adds to the existing mass of ice.



Top view (in polarized light) showing the boundaries between individual ice crystals radiating from the center of the apparatus. Water surrounds this central ice disk.



Wilen and Dash/Phys. Rev. Lett.

Side view of apparatus used to study frost heave dynamics.

Physicists have now studied this temperature-dependent flow at the flat surface of a single crystal of ice. These experiments confirm the presence of a thin layer of supercooled water alongside the ice crystal. The flow induced by a temperature gradient in the liquid layer causes the ice to grow at right angles to the water-ice interface.

Larry A. Wilen and J.G. Dash of the University of Washington in Seattle report their findings in the June 19 PHYSICAL REVIEW LETTERS.

The research hinges on the idea that a solid in contact with its melted counterpart often develops a film of liquid along the interface; this film has a temperature lower than the solid's normal melting point. The effect is called surface melting.

In 1989, Dash proposed that modest temperature differences can drive flows in these liquid surface films and contribute to frost heave. In soil, this chilled but unfrozen water tends to migrate along temperature gradients toward lower temperatures, eventually accumulating and freezing into ice "lenses." It is these ice accumulations, created by water drawn to the freezing sites, that force the soil apart, both lifting and compacting it.

To test the idea on a microscopic scale, Wilen and Dash used an apparatus formed by punching a circular hole in a fiberglass wafer, then closing the hole with a glass plate on the bottom and a flexible, plastic sheet on the top (see diagram). They filled the resulting cavity with water, then cooled its center to a temperature below water's freezing point, while keeping its outer edge at a higher temperature.

Touching the membrane with a cotton tip chilled in liquid nitrogen initiated ice formation at the center. After the ice disk finished growing, the researchers used a microscope to examine changes taking place at an ice crystal's edge.

They observed that over several days, a pronounced ice ridge develops along the disk's rim, pushing up the flexible membrane. The formation of such a structure serves as evidence of surface melting and liquid flow along the thin film of water between the ice and the membrane.

"The ridge is due to water at the ice-membrane interface flowing radially inward toward the colder region," Wilen says. "This liquid film gets thinner and thinner as the interface gets colder and colder. Eventually, the melted layer becomes so thin that no more water can flow inward. The water freezes onto the ice to create the ridge."

Wilen and Dash also noted that the presence of ice crystal boundaries seems to greatly increase liquid movement. "You can see a distortion of the shape of the membrane that's much bigger than what you see just at the edge from a single grain [or crystal]," Wilen says. "Grain boundaries may play a very big role in enhancing this flow."

The researchers are now taking a closer look at the effects of impurities and crystal boundaries on liquid movement and freezing. —*I. Peterson*

Heart-y risks from breathing fine dust

Nearly 1,200 hospitalizations for heart disease in the Detroit area each year may trace to fine, dust-sized particles in the air—and perhaps to carbon monoxide, a new study suggests. If the associations hold up, any national tally of heart disease emergencies fostered by these pollutants would be dramatically higher.

The Environmental Protection Agency is currently reevaluating its 1987 particulates standard. One impetus has been a spate of studies showing that daily hospital admissions and deaths from respiratory disease tend to fluctuate in near lockstep with variations in airborne dust—even when particulate levels fall within federal limits.

The new study departs from earlier analyses by following up on hints of a tantalizing cardiovascular link that appeared in several mortality studies. The researchers selected Detroit, explains Joel Schwartz of the Harvard School of Public Health in Boston, because it was the largest region for which daily measurements are kept of the most respirable particles—those 10 micrometers and smaller. EPA regulates just these PM-10 particulates.

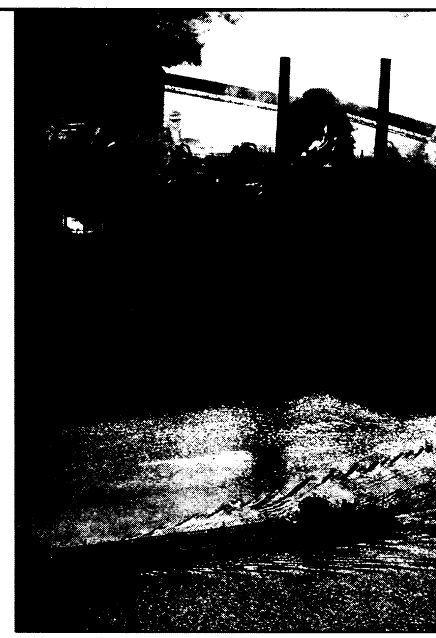
Along with Robert Morris of the Medical College of Wisconsin in Madison, Schwartz looked for correlations between heart disease and either weather or any of several different pollutants, including sulfur dioxide, ozone, and PM-10.

Only PM-10 correlated with hospital admissions for ischemia (problems linked to reduced blood flow), they report in the July 1 AMERICAN JOURNAL OF EPIDEMIOLOGY. For each 100 microgram increase in PM-10 per cubic meter ($\mu g/m^3$) of air, admissions climbed roughly 6 percent. Moreover, Schwartz notes, their analyses show no sign of any threshold below which this trend disappears.

The pair also linked a nearly 8 percent increase in hospital admissions for congestive heart failure (an inability of the heart to pump out all the blood that returns to it) with each 100 $\mu g/m^3$ increase in PM-10 or 4 parts per million increase in carbon monoxide (CO). By contrast, they turned up no link between any of the factors and admissions for heart arrhythmias.

This study extends to individual heart ailments the PM-10 trends seen in mortality studies, notes Patrick L. Kinney of the Columbia University School of Public Health in New York City.

"But the most interesting thing to me was the CO effect," says David Fairley of the Bay Area Air Quality Management District in San Francisco. He says most analysts have largely ignored this persistent auto pollutant because ambient levels had not been associated with serious health effects.



Dusty pollutants from combustion and industrial activities appear capable of aggravating some heart conditions.

How particulates might foster cardiovascular emergencies remains a big, unanswered question. However, Schwartz notes, data he published in the January 1994 ENVIRONMENTAL RESEARCH indicate that aggravation of some accompanying respiratory disease accounted for roughly half the PM-10-linked cardiovascular deaths he identified in Philadelphia 4 years ago (SN: 4/6/91, p.212). —*J. Raloff*