What we can learn from the biggest extinction in the history of Earth

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Approximately 250 million years ago, vast numbers of species disappeared from Earth. This mass-extinction event may hold clues to current global carbon cycle changes, according to Jonathan Payne, assistant professor of geological and environmental sciences.

Payne, a paleobiologist who joined the Stanford faculty in 2005, studies the Permian-Triassic extinction and the following 4 million years of instability in the global carbon cycle. In the July issue of the *Geological Society of America Bulletin*, Payne presented evidence that a massive, rapid release of carbon may have triggered this extinction.

"People point to the fossil record as a place where we can learn about how our actions today may affect the future course of evolution," Payne said. "That's certainly true: The deep geologic record provides context for modern events. We may miss very important processes or underestimate the magnitude of changes in the future by using only the past couple thousand years as a baseline."

Great Bank of Guizhou

Payne has spent the past five years unearthing the deep geologic record in south China. The kilometer-thick, limestone fossil beds at the Great Bank of Guizhou formed in shallow ocean waters during the late Permian and early Triassic periods. As the ocean floor sank, new, younger layers of limestone formed on top of deeper, older ones. Since

then, plate tectonics have turned these rocks on their side. Now, Payne and his colleagues can walk back in time across the formerly horizontal layers.

Marine fossil beds such as these offer two advantages for someone studying broad patterns in the history of life, according to Payne. Because ocean waters cover large areas for long periods of time and somewhat protect the underlying rocks from erosion, marine fossil beds tend to be physically larger and cover a longer period of time with finer temporal resolution.

More than 90 percent of all marine species disappeared from the Great Bank of Guizhou and other end-Permian fossil formations 250 million years ago. Land plants and animals suffered similar losses. Douglas Erwin, curator of the Paleozoic invertebrates collection at the Smithsonian National Museum of Natural History, has dubbed this event "the greatest biodiversity crisis in the history of life." An unusually long period of time passed before biological diversity began to reappear. Scientists disagree on the causes of this extinction. However, nearly all explanations cite the high levels of greenhouse gases, including carbon dioxide, low levels of oxygen in the oceans and high levels of toxic gases.

Siberian Traps

In 1991, scientists reported that the largest known volcanic event in the past 600 million years occurred at the same time as the end-Permian extinction. Magma extruded through coal-rich regions of the Earth's crust and blanketed a region the size of the continental United States with basalt to a depth of up to 6 kilometers. The eruptions that formed the Siberian Traps not only threw ash, debris and toxic gases into the atmosphere but also may have heated the coal and released vast quantities of carbon dioxide and methane into the atmosphere.

Rapid release of these greenhouse gases would have caused the oceans first to become acidic and then to become supersaturated with calcium carbonate. In the July Bulletin, Payne presents evidence that underwater limestone beds around the world eroded at the time of the end-Permian extinction. This finding, coupled with geochemical evidence for changes in the relative abundances of carbon isotopes, strongly suggests an acidic marine environment at the time of the extinction. The rock layers immediately covering this eroded surface include carbonate crystal fans, which indicate oceans supersaturated with calcium carbonate.

"This end-Permian extinction is beginning to look a whole lot like the world we live in right now," Payne said. "The good news, if there is good news, is that we have not yet released as much carbon into the atmosphere as would be hypothesized for the end-Permian extinction. Whether or not we get there depends largely on future policy decisions and what happens over the next couple of centuries."

Coral reefs

Payne plans to learn more about the causes and consequences of this massive extinction event this summer. Three students left Aug. 1 to join him in southern China for four weeks of field studies.

If volcanic activity released sufficient quantities of carbon into the air within less than 100,000 years, the Earth would have transiently cooled and then experienced a prolonged period of global warming, Payne said. This summer, Ellen Schaal, a graduate student in the Department of Geological and Earth Sciences, will use one geochemical index to try to understand how climate did change during the end-Permian period.

Two other students will examine coral reef structures. The Great Bank of Guizhou contains the fossilized reefs from just before and just after this extinction event. Undergraduate Mindi Summers hopes to describe the

ecological structure of coral reefs just before the extinction, and graduate student Brian Kelley will study the development and diversification of reefs after the global carbon cycle began to stabilize.

Reef communities are a sort of canary in the mineshaft, Payne explained. Today, coral reef health is considered a measure of environmental stability. When stressed by environmental conditions, the algae that inhabit the reef leave, and the reef loses color-and one reason why algae might leave is temperature. For example, when ocean temperatures rise during El Niño years, corals bleach. This type of immediate response to environmental change is hard to track in the geologic record.

"We hope to reconcile the short-term processes we observe operating in the modern world with the very long time scales seen in the geologic record," said Seth Finnegan, a postdoctoral scholar in Payne's lab.

Source: Stanford University

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