Cold case: Siberian hot springs reveal ancient ecology (w/ video)

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The summit of Karymsky Volcano stands at 5,000 feet, and it regularly sends ash to elevations of 25,000 feet and beyond. These eruptions are monitored both for scientific reasons and because the plumes of ash and dust pose a threat to commercial aviation. Credit: Courtesy of Albert Colman

(PhysOrg.com) -- Exotic bacteria that do not rely on oxygen may have played an important role in determining the composition of Earth's early atmosphere, according to a theory that UChicago researcher Albert Colman is testing in the scalding hot springs of a volcanic crater in Siberia.

He has found that bacteria at the site produce as well as consume carbon monoxide, a surprising twist that scientists must take into account as they attempt to reconstruct the evolution of Earth's early atmosphere.

Colman, an assistant professor in geophysical sciences, joined an American-Russian team in 2005 working in the Uzon Caldera of eastern Siberia's Kamchatka Peninsula to study the microbiology and geochemistry of the region's hot springs.

Colman and his colleagues focused on anaerobic carboxydotrophs — microbes with a physiology as exotic as their name. They use carbon monoxide mostly for energy, but also as a source of carbon for the production of new cellular material.

This carbon monoxide-based physiology results in the microbial production of hydrogen, a component of certain alternative fuels. The research team thus also sought to probe biotechnological applications for cleaning carbon monoxide from certain industrial waste gases and for biohydrogen production.

"We targeted geothermal fields," Colman says, "believing that such environments would prove to be prime habitat for carboxydotrophs due to the venting of chemically reduced, or in other words, oxygen-free and methane-, hydrogen-, and carbon dioxide-rich volcanic gases in the springs."

The team did discover a wide range of carboxydotrophs. Paradoxically, Colman found that much of the carbon monoxide at the Kamchatka site was not bubbling up with the volcanic gases; instead "it was being produced by the microbial community in these springs," he says. His team began considering the implications of a strong microbial source of carbon monoxide, both in the local springs but also for the early Earth.

The Great Oxidation Event

Earth's early atmosphere contained hardly any oxygen but relatively large amounts of carbon dioxide and possibly methane, experts believe. Then during the so-called Great Oxidation Event about 2.3 to 2.5 billion years ago, oxygen levels in the atmosphere rose from vanishingly small amounts to modestly low concentrations.

"This important transition enabled a widespread diversification and proliferation of metabolic strategies and paved the way for a much later climb in oxygen to levels that were high enough to support animal life," Colman says.

The processing of carbon monoxide by the microbial community could have influenced atmospheric chemistry and climate during the Archean, an interval of Earth's history that preceded the Great Oxidation Event.

Previous computer simulations rely on a primitive biosphere as the sole means of removing near-surface carbon monoxide produced when the sun's ultraviolet rays split carbon dioxide molecules. This theoretical sink in the biosphere would have prevented substantial accumulation of atmospheric carbon monoxide.

"But our work is showing that you can't consider microbial communities as a one-way sink for carbon monoxide," Colman says. The communities both produce and consume carbon monoxide. "It's a dynamic cycle."

Some of the springs in Uzon Caldera are boiling hot, reaching temperatures of

210 degrees Fahrenheit. Other springs are cooler, but still scalding hot. "That factors into how we approach these springs with special gear to protect ourselves should we happen to have a leg punch through a thin crust into scalding water," Albert Colman says. Credit: Courtesy of Albert Colman

Colman's calculations suggest that carbon monoxide may have nearly reached percentage concentrations of 1 percent in the atmosphere, tens of thousands of times higher than current concentrations. This in turn would have exerted influence on concentration of atmospheric methane, a powerful greenhouse gas, with consequences for global temperatures.

Toxic concentrations

Furthermore, such high carbon monoxide concentrations would have been toxic for many microorganisms, placing evolutionary pressure on the early biosphere.

"A much larger fraction of the microbial community would've been exposed to higher carbon monoxide concentrations and would've had to develop strategies for coping with the high concentrations because of their toxicity," Colman says.
Colman and UChicago graduate student Bo He have conducted fieldwork in both Uzon and California's Lassen Volcanic National Park. Colman has most recently journeyed to Kamchatka for additional fieldwork in 2007 and 2010.

"This fantastic field site has a wide variety of hot springs," he says. "Different colors, temperatures, chemistries, different types of micro-organisms living in them. It's a lot like Yellowstone in certain respects."

Lassen's springs have a narrower range of acidic chemistries, yet microbial production of carbon monoxide appears to be widespread in both settings.

Collaborator Frank Robb of the University of Maryland, Baltimore, lauds Colman for his "boundless enthusiasm" and for his "meticulous preparation," much-needed qualities to ensure the safe transport of delicate instruments into the field.

Some of the microbial life within the caldera's complex hydrothermal system may survive in even more extreme settings than scientists have observed at the surface, Colman says.

"One thing we really don't know very well is the extent to which microbial communities beneath the surface influence what we see at the surface, but that's possible as well," Colman says.

"We know from culturing deep-sea vent microbes that they can live at temperatures that exceed the temperatures we're observing right at the surface, and some of the turn out to metabolize carbon monoxide."

Provided by University of Chicago

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