Mechanism for Burgess Shale-type preservation

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The Burgess Shale of British Columbia is arguably the most important fossil deposit in the world, providing an astounding record of the Cambrian "Explosion," the rapid flowering of complex life from single-celled ancestors. While most of the fossil record is comprised of shells, teeth and bones, the Burgess Shale preserves the softer bits—the eyes, guts, gills and other delicate structures—of animals belonging to Earth's earliest complex ecosystems a half a billion years ago. The process for this extraordinary preservation remained a mystery since the initial discovery of the Burgess Shale in 1909 until now.

A team of researchers led by Robert Gaines, of Pomona College (USA), and Emma Hammarlund, of the Nordic Center for Earth Evolution (Denmark), claims to have unlocked the mystery of the Burgess Shale in their study, "Mechanism for Burgess Shale-type preservation," published in Monday the 5th of March in the *Proceedings of the National Academy of Sciences*. In addition to Gaines and Hammarlund, the team includes researchers from t Yunnan University (China), the University of Leicester (UK) and Guizhou University (China).

The team collected evidence from the Burgess Shale, two new drill cores from the Chengjiang deposit in Yunnan Province, China, and from five other principal Burgess Shale-type deposits in Utah and China. Using geochemical analysis involving the sulfur isotypes from pyrite (fool's gold), they found a striking global pattern that unlocks the key to the unusual preservation process.

The process begins with the very rapid burial of organisms in mud layers with little to no oxygen. The critical discovery by the research team was a layer of calcium carbonate cement, in all of the sites, laid on the sea floor soon after burial of the fossils in mud. This mineral carpet acted as a barrier to the microbial communities that would normally consume soft tissue organisms in two-three weeks. Because the microbes were prevented from degrading the soft tissues completely, the organic remains of animals were conserved, leading to the preservation of the extraordinary fossils found today.

"What turned out to be the important key for this type of preservation is the chemistry of the global sea water," explains Gaines. "The preservation was greatly aided by enhanced calcium carbonate concentrations in the Cambrian oceans and by depletion of oxygen and sulfate. Importantly, low oxygen concentrations in the global oceans during this interval of time limited the amount of sulfate, an important microbial nutrient."

In the past, researchers have focused on the fossils themselves, rather than the details of the sediments and their chemistry. Gaines and Hammarlund found it was necessary to unlock the mystery of the strange preservation—a sign that the environment was not normal.

The drill cores from the Chengjiang site were important because the heavy rains from the Himalayan monsoons in the area leach minerals, including pyrite and calcium carbonate, from the rocks that are exposed on the surface. With these cores, the team's unique collection of samples led to the recognition that unique aspects of early Paleozoic seawater chemistry that were key to the unusual Burgess-type soft-bodied fossil preservation—the low sulfate concentration, low-oxygen bottom water conditions, and the mineral carpet that aided in choking the hungry microbes—was a striking global pattern.

"I had little idea of what to expect from the geochemical data, which rarely can provide a 'silver bullet,' says Gaines. "I was literally floored. I have rarely seen geochemical data so convincing. My initial hypothesis was validated by a consistent and worldwide pattern."

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