Mineral kingdom has co-evolved with life

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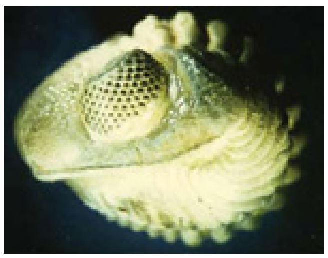

Fossil trilobite.

(PhysOrg.com) -- Evolution isn't just for living organisms. Scientists at the Carnegie Institution have found that the mineral kingdom co-evolved with life, and that up to two thirds of the more than 4,000 known types of minerals on Earth can be directly or indirectly linked to biological activity. The finding, published in *American Mineralogist*, could aid scientists in the search for life on other planets.

Robert Hazen and Dominic Papineau of the Carnegie Institution's Geophysical Laboratory, with six colleagues, reviewed the physical, chemical, and biological processes that gradually transformed about a dozen different primordial minerals in ancient interstellar dust grains to the thousands of mineral species on the present-day Earth. (Unlike biological species, each mineral species is defined by its characteristic chemical makeup and crystal structure.)

"It's a different way of looking at minerals from more traditional approaches," says Hazen. "Mineral evolution is obviously different from Darwinian evolution—minerals don't mutate, reproduce or compete like living organisms. But we found both the variety and relative abundances of minerals have changed dramatically over more than 4.5 billion years of Earth's history."

All the chemical elements were present from the start in the Solar Systems' primordial dust, but they formed comparatively few minerals. Only after large bodies such as the Sun and planets congealed did there exist the extremes of temperature and pressure required to forge a large diversity of mineral species. Many elements were also too dispersed in the original dust clouds to be able to solidify into mineral crystals.

As the Solar System took shape through "gravitational clumping" of small, undifferentiated bodies—fragments of which are found today in the form of meteorites—about 60 different minerals made their appearance. Larger, planet-sized bodies, especially those with volcanic activity and bearing significant amounts of water, could have given rise to several hundred new mineral species. Mars and Venus, which Hazen and coworkers estimate to have at least 500 different mineral species in their surface rocks, appear to have reached this stage in their mineral evolution.

However, only on Earth—at least in our Solar System—did mineral evolution progress to the next stages. A key factor was the churning of the planet's interior by plate tectonics, the process that drives the slow shifting continents and ocean basins over geological time. Unique to Earth, plate tectonics created new kinds of physical and chemical environments where minerals could form, and thereby boosted mineral diversity to more than a thousand types.

What ultimately had the biggest impact on mineral evolution, however, was the origin of life, approximately 4 billion years ago. "Of the approximately 4,300 known mineral species on Earth, perhaps two thirds of them are biologically mediated," says Hazen. "This is principally a consequence of our oxygen-rich atmosphere, which is a product of photosynthesis by microscopic algae." Many important minerals are oxidized weathering products, including ores of iron, copper and many other metals.

Microorganisms and plants also accelerated the production of diverse clay minerals. In the oceans, the evolution of organisms with shells and mineralized skeletons generated thick layered deposits of minerals such as calcite, which would be rare on a lifeless planet.

"For at least 2.5 billion years, and possibly since the emergence of life, Earth's mineralogy has evolved in parallel with biology," says Hazen. "One implication of this finding is that remote observations of the mineralogy of other moons and planets may provide crucial evidence for biological influences beyond Earth."

Citation: Robert M. Hazen, Dominic Papineau, Wouter Bleeker, Robert T. Downs, John M. Ferry, Timothy J. McCoy, Dimitri Sverjensky and Hexiong Yang (2008) Mineral evolution. *American Mineralogist.*

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