Calcium Carbonate formation in biology: the involvement of an amorphous calcium carbonate precursor phase

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Controlled mineral formation in biology takes place in intra- or extracellular privileged micro-environments. Acidic macromolecules are involved in nucleation, modulation of mineral growth and cessation of growth, all this taking place in a saturated solution. Beniash et al (1) showed that in the formation of the sea urchin larval spicule, this general scenario is different. After an initial crystal of calcite is formed, further growth of the spicule takes place by deposition of amorphous calcium carbonate (ACC), which subsequently, in part, transforms into calcite. Furthermore there is no evidence for the presence of a saturated solution in the vesicle in which spicule formation takes place (2). Weiss et al (3) demonstrated that an ACC precursor phase is also involved in the formation of aragonite in mollusk larval shells. We also note that in the formation of the teeth of certain adult mollusks (chitons), an amorphous calcium phosphate phase is the precursor of crystalline dahllite, and the poorly ordered ferrihydrite phase is the precursor of magnetite(4). We thus suspect that the use of a precursor strategy in biomineralization, including calcium carbonate formation, may be widespread. Studies of biogenic stable ACC show that they often contain large amounts of Mg and/or phosphate, and the associated macromolecules are Glu/Gln-rich, as opposed to the Asp-rich proteins associated with crystalline calcium carbonate. In vitro studies show that Mg and the Glu/Gln-rich proteins can stabilize the ACC phase(5). Biological calcium carbonate formation thus takes place under conditions quite different from the marine environment, raising questions as to how, despite this, mollusks do form their shells in isotopic equilibrium with sea water.

References

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Records of the ancient Martian magnetic field and climate in ALH84001

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Although Mars does not presently appear to have a global magnetic field, strong crustal fields have recently been detected by the Mars Global Surveyor above surfaces formed ~3 or more billion years ago (Ga). We present magnetic and textural studies of Martian meteorite ALH84001 demonstrating that 4 Ga carbonates containing magnetite and pyrrhotite carry a stable natural remanent magnetization. Using the data of Bogard and Garrison for $^{40}Ar/^{39}Ar$ thermochronology, we show that ALH84001 carbonates have probably been well below the Curie point of magnetite since near the time of their formation.

This means that their magnetization originated at 3.9-4.1 Ga on Mars. This magnetization is at least 500 million years (My) older than that known in any other planetary rock, and its strong intensity suggests that Mars had generated a geodynamo and global magnetic field within 450-650 My of its formation. The intensity of this field was roughly within an order of magnitude of that at the surface of the present day Earth, sufficient for magnetotaxis by the bacteria whose magnetofossils have been reported in ALH84001 and possibly for the production of the strong crustal anomalies. Chromite in ALH84001 may retain even older records of Martian magnetic fields, possibly extending back to near the time of planetary formation.

Our data also suggest that the meteorite has probably not been shocked above ~1 GPa since 4 Ga. This provides an explanation for why ALH84001 contains a sample of an apparently ancient Martian atmosphere that is less evolved relative to that currently on the planet. That these gases are enriched in light isotopes of H and N relative to present-day values supports the hypothesis that significant atmospheric loss has occurred on Mars since 4 Ga. Our thermochronology calculations also suggest that for the last four billion years, average surface temperatures on Mars may not been much higher than the present-day cold (~-70 °C) conditions.