The composition of ancient meteorites

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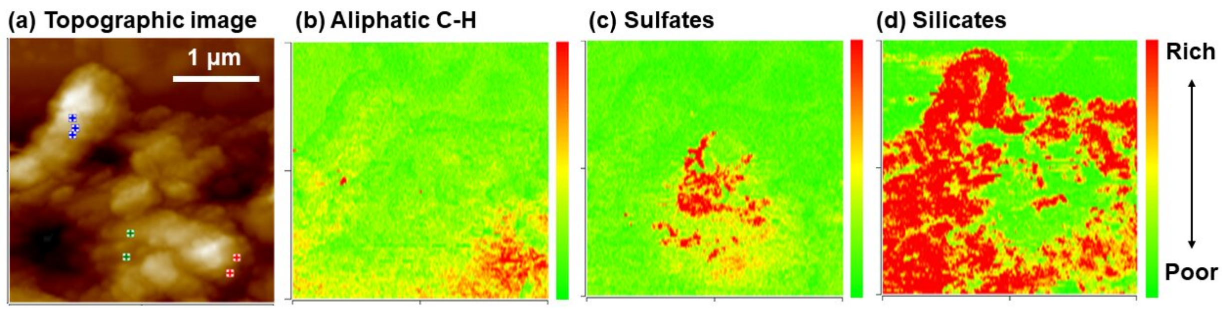

Scientists use more powerful imaging techniques to visualize distributions of organic matter (aliphatic C-H) and minerals (sulfates and silicates) in ancient meteorite. Credit: Yokohama National University

A team of Japanese and American scientists has visualized meteorite components at higher resolution than ever before. Their efforts have resulted in an enhanced understanding of substances inside carbonaceous chondrites, the organic-compound-containing meteorites that land on Earth. These substances include hydrogen, carbon, nitrogen and water, all of which are needed for life.

The study was published online on January 2, 2019 in *Proceedings of the National Academy of Sciences* (*PNAS*).

Carbonaceous chondrites are made of materials such as rocks, organics, ice and fine grain dust, most of which were formed in the solar system. The origin of organic matter that is found in meteorites dates back to the formation of the solar system, or approximately 4.5 billion years ago. Therefore, when found on Earth and analyzed in detail, these carbonaceous chondrites are helpful for understanding the history of the solar system, the formation of organic compounds, the presence of water on Earth, and ultimately, the origin of life.

Being able to visualize organic and inorganic components of meteorites that have landed on Earth is important because it enables researchers to understand the effects of external factors such as water and temperature. More specifically, a method that enables researchers to better see and analyze the molecular structures ultimately helps them understand the spatial relationships between organic matter and minerals. This is vital for tracing the formation as well as the evolution of organic matter and ultimately understanding the history of the formation of the solar system. Also, understanding the origin of meteorites is crucial for determining the origins of both water and life on the planet.

However, studies to date have been limited with methods and microscopy that provided images at much lower resolutions. Therefore, formations and evolutions of extraterrestrial organic matter have thus far remained fairly unknown and have only been analyzed after extraction, which is a complicated multi-step process that is prone to many types of methodological errors.

"Researchers have recently mostly conducted analysis for organic matter to see the distributions and associations with inorganic compounds that may help us understand chemistry such as mineral catalyzed synthesis of organic matter, during alteration processes in the meteorite parent asteroids and historic dust processes in the early solar system. However, since the components of meteorites are very fine, microscopic techniques to analyze such distributions and associations are limited," says Yoko Kebukawa, Ph.D., an Associate Professor at the Faculty of Engineering, Yokohama National University in Japan and the corresponding author of the paper.

Specific to this research, the focus has been on visualizing components of carbonaceous chondrites via a powerful microscopy method that provides images of meteorite components at much better resolutions. This method, atomic force microscopy-based infrared spectroscopy (AFM-IR) enabled the researchers to view the components of two carbonaceous chondrites, the Murchison meteorite and the Bell meteorite at much higher resolutions. This, in turn, provided much more detailed images than those that have been obtained thus far.

"The AFM-IR technique enabled us to overcome the limitation of poor spatial resolution of infrared spectroscopy to see the fine details of organic matter as it is distributed in meteorites and associations of minerals," Kebukawa adds.

In the future, the team plans to focus on the roles of minerals in the formations and evolution of organic matter in meteorites during external processes that affect the bodies they come from. According to Kebukawa, "This requires two things, namely analyses of meteorites that have been altered in several ways as well as proper experimental simulations of these alteration processes that will enable the aforementioned methods."

More information: Yoko Kebukawa et al, Nanoscale infrared imaging analysis of carbonaceous chondrites to understand organic-mineral interactions during aqueous alteration, *Proceedings of the National Academy of Sciences* (2019). DOI: 10.1073/pnas.1816265116

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