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What clues does an asteroid hold about life on Earth?

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Abstract

Have you ever wondered what is inside an asteroid? NASA's OSIRIS-REx mission brought rock samples from the asteroid Bennu back to Earth. We were able to study some of them. We made sure our samples stayed clean and did not touch air or dirt from Earth. We used infrared light, X-rays, and powerful microscopes to see what the rocks were made of and how they looked inside.

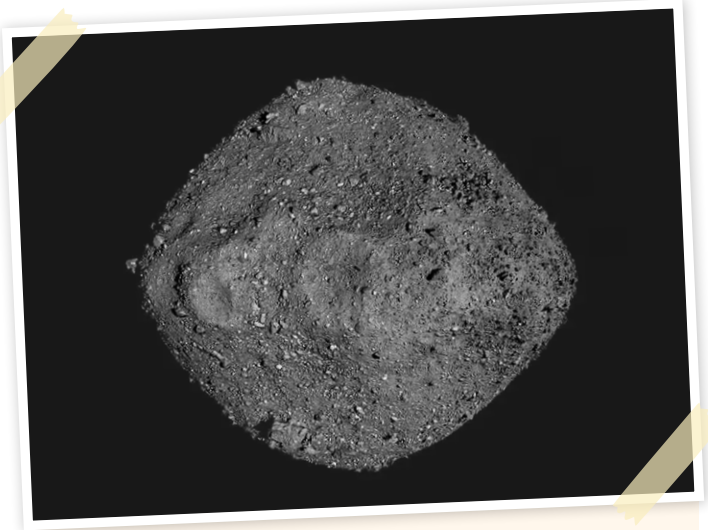
We found very thin layers of an unusual plastic-like material inside our Bennu samples. Some layers were folded, suggesting that something pushed them around while they were soft. The material is rich in carbon, nitrogen, and oxygen, which are important elements for life. We found evidence for complex chemical reactions that happened in space a long time ago! By comparing what we find in space with what we learn on Earth, scientists can begin to figure out more about the building blocks of life.

Introduction

One of the biggest questions in science is "How did life start?" One way researchers study this is by looking at **asteroids**. An asteroid is a small rocky object that orbits the Sun. Most are billions of years old. We know that some asteroids contain ice, which melts as the asteroids slowly warm up. This process can take a million years or more and happened over 4.5 billion years ago. This allowed chemical reactions to occur. But we don't know exactly what happens during this time. Studying this process helps scientists understand how complex materials could have formed. This could even help scientists learn about the origin of life!

In 2016, NASA sent the OSIRIS-REx spacecraft to collect rock samples from an asteroid named Bennu. Bennu is a small asteroid that passes near the Earth every 6 years. When the samples returned to Earth in 2023, many scientists were able to study them.

Our team wondered if Bennu had **organic molecules** that contained nitrogen. These are chemicals essential for life. We also wondered how the rocks in Bennu formed. By studying rock samples from Bennu, we hoped to learn what materials were present in space long ago.



An image of the asteroid Bennu taken by the OSIRIS-REx spacecraft. This asteroid passes by Earth every 6 years, which allows scientists to collect samples. **Photo:** NASA

Methods

We transported rock samples from Bennu to our laboratories. We stored them carefully to avoid **contamination**. We made sure they didn't touch air, moisture, or dirt from Earth. This helped keep them just like they were in space.

We crushed the rocks gently and then separated them to look at smaller pieces. We investigated three main properties of our samples.

1. The **elements** our samples contained. We were especially interested in elements like nitrogen, carbon, and oxygen. We used a **transmission electron microscope** technique to figure this out.
2. How the elements were arranged. We used **infrared light** and **X-rays** to help us see what **chemical bonds** our samples contained. This could help us determine what types of molecules were in our samples.
3. The microscopic structure of our samples. We used a beam of **ions** to shave layers off our sample. Then we used our microscope to help us see small internal structures. That helped us discover how the rock changed as it formed.

Results

We found that our Bennu samples contained a lot of nitrogen, carbon, and oxygen. These elements are important for forming complex molecules that support life.

We found chemical groups with bonds between:

- carbon and oxygen
- carbon and nitrogen
- carbon and hydrogen
- nitrogen and hydrogen
- oxygen and hydrogen

Many of these chemical groups are also found in **plastics** and life here on Earth.

Some of our samples seemed smooth and flexible as we prepared them for our microscope scans (Figure 1). We found that our samples contained tiny **crystals** made of calcium, carbon, and oxygen trapped inside multiple layers. The shape of the layers suggests that they were deposited on surfaces at some point.

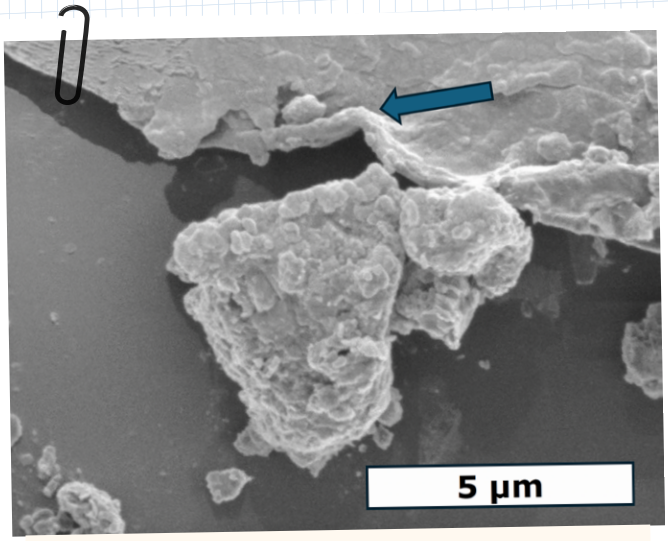


Figure 1: The arrow points to a dent in one of the organic particles, showing that the material is soft.

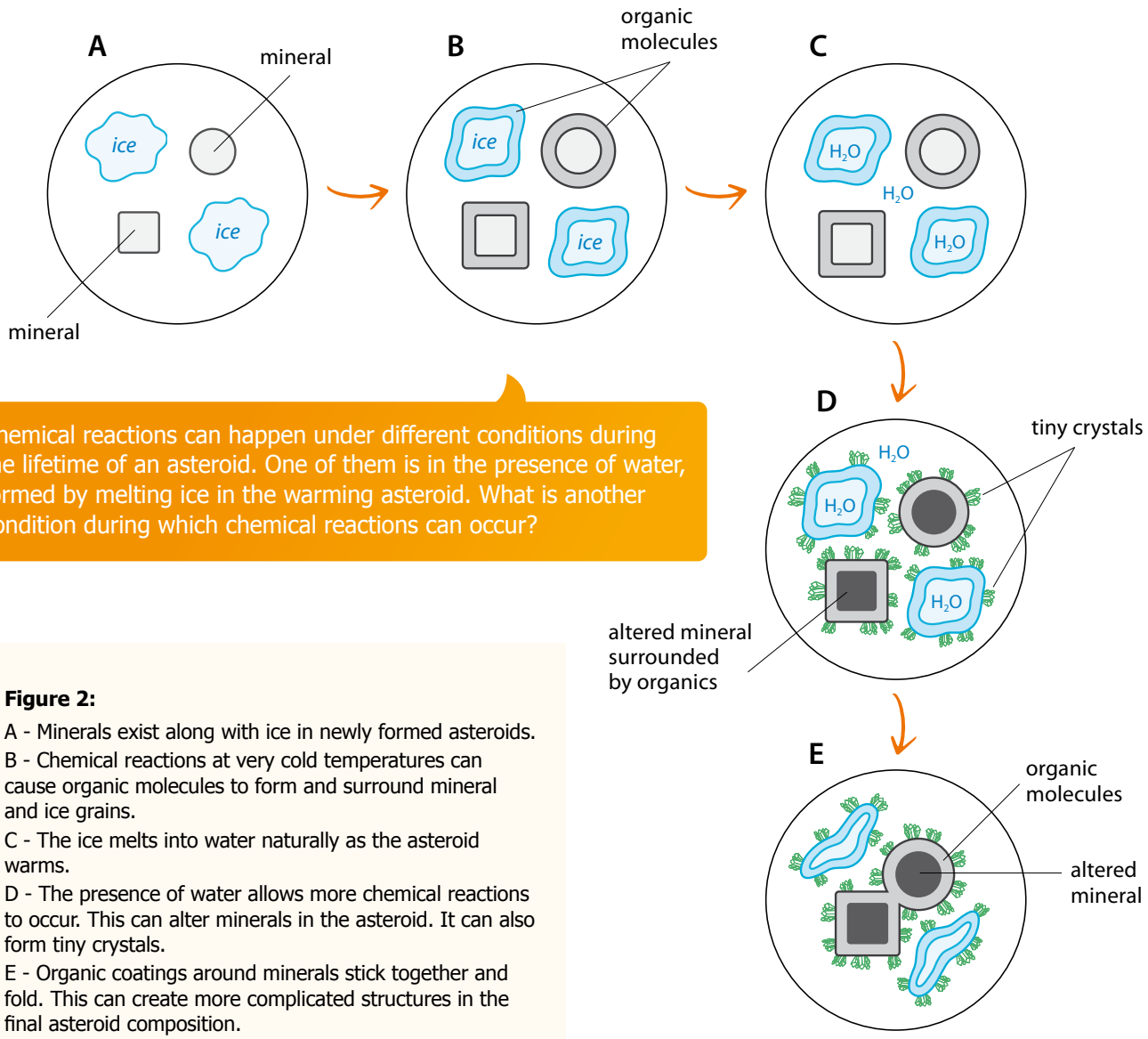
Discussion

The plastic-like material inside Bennu is rare! It gives us a glimpse into how Bennu changed over time. We found carbon- and nitrogen-rich layers that had tiny crystals inside. When Bennu first formed, it was most likely frozen. Later, it heated up, and the water ice in the asteroid melted. The rare material we found probably did not form in water. Water would have separated the elements differently. That means it formed before liquid water was present, while Bennu still had ice! So, it formed through **cryogenic** reactions, or reactions that occur at very cold temperatures.

The shape of the layers suggests that water later pushed the plastic-like material around and mixed it with the crystals. It is possible that the chemical bonds also changed a little bit from sitting in the water. This could explain how the layers in our samples formed (see Figure 2 on p.3).

Our discovery shows that complex chemical reactions

happened in space a long time ago. The presence of carbon, nitrogen, and oxygen is especially interesting. Molecules containing nitrogen, like **amino acids**, are essential to life on Earth. One hypothesis is that these essential molecules originally came from asteroids that crashed into Earth. Our findings show that these types of molecules **can** form on asteroids. But a lot more research will be needed to fully understand where these essential molecules on Earth came from. Hopefully, further research about what asteroids are made of can help!



Chemical reactions can happen under different conditions during the lifetime of an asteroid. One of them is in the presence of water, formed by melting ice in the warming asteroid. What is another condition during which chemical reactions can occur?

Figure 2:

A - Minerals exist along with ice in newly formed asteroids.

B - Chemical reactions at very cold temperatures can cause organic molecules to form and surround mineral and ice grains.

C - The ice melts into water naturally as the asteroid warms.

D - The presence of water allows more chemical reactions to occur. This can alter minerals in the asteroid. It can also form tiny crystals.

E - Organic coatings around minerals stick together and fold. This can create more complicated structures in the final asteroid composition.

Conclusion

We are still figuring out how life formed in the early Solar System. Scientists study materials here on Earth to understand how they change over time. These skills help them investigate materials found in asteroids like Bennu, which formed far away in space. You can do the same by comparing what you learn at home or in school with what you observe in the world around you. By staying curious and exploring science, you could one day help answer some of the biggest questions about life on Earth.

Glossary of Key Terms

Amino acid - a small molecule that joins together with others to make proteins in living things.

Asteroid - a small rocky body that orbits the Sun.

Chemical bond - a force that holds atoms together to form a molecule or compound.

Contamination - when a sample becomes mixed with unwanted materials, such as air, water, or dirt. This can change the results of testing.

Cryogenic - extremely cold, far colder than a normal freezer.

Crystal - a solid material in which the particles are arranged in a neat, repeating pattern.

Element - a substance made from only one type of atom.

Infrared light - a type of light that we cannot see but that can be used to study materials and measure heat.

Ion - an atom or molecule that has gained or lost electrons, giving it an electrical charge.

Organic molecules - carbon-based molecules that are often found in living things or in materials related to life.

Plastic - a material made of long chains of molecules called polymers that can be shaped or molded when soft and then harden into a solid.

Transmission electron microscope - a powerful microscope that uses an electron beam, rather than light, to see through a material. It can show internal structures at the atomic level.

X-rays - a type of electromagnetic radiation with shorter wavelengths than visible light. It tells us what kinds of elements and crystals are present.

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Check your understanding

1 What are the elements that are most important for life? What examples can you think of that include these elements?

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2 We minimized the asteroid samples' exposure to air. Why is this important, and what do you think could happen if they had been exposed to air or moisture?

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3 We found crystals trapped inside the layers of material. What do these crystals tell us about how the material formed?

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4 Imagine that you are on a team looking at a brand-new asteroid sample. What is one thing that you would look for?

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5 Scientists study materials from asteroids to understand how life may have started many years ago. Do you think that studying space is important for people on Earth? Give one good example of how this research could be useful.