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Researchers discover how atmospheric feldspar dust contributes to cloud formation

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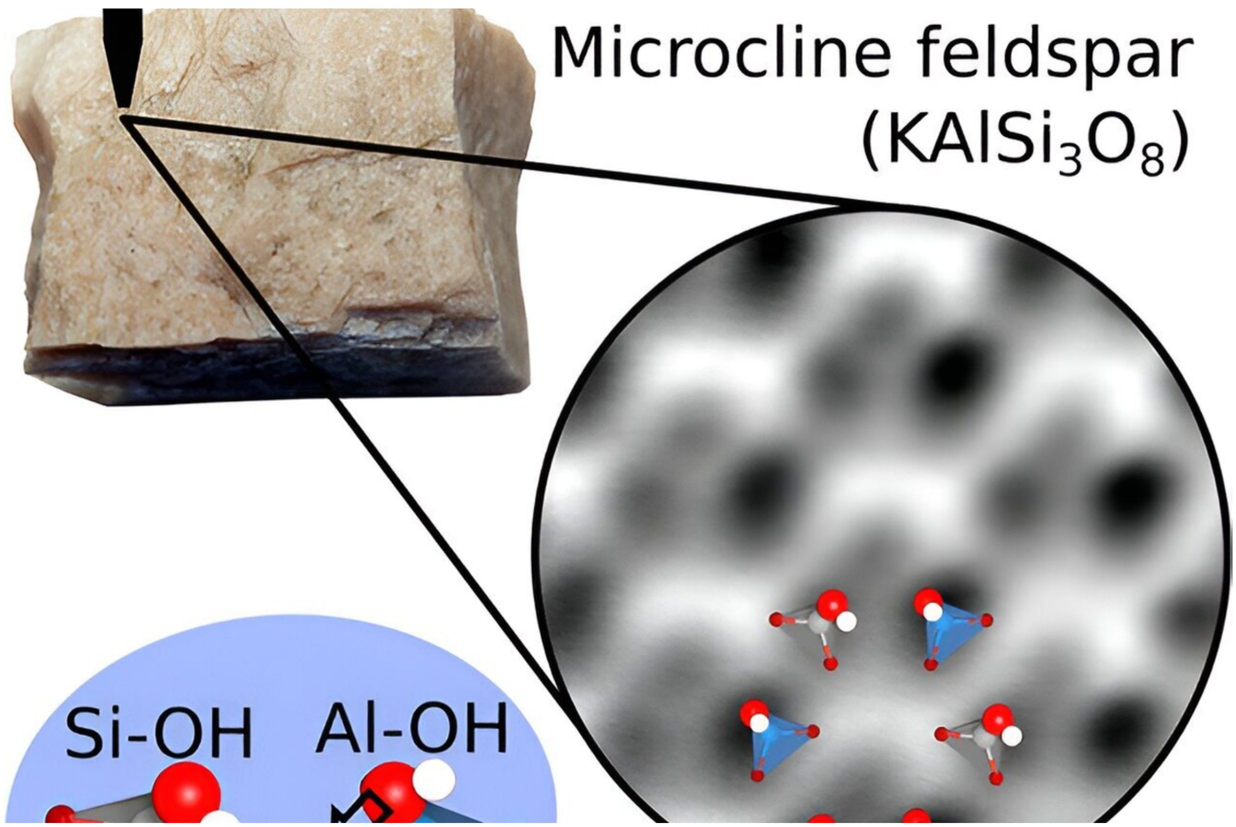

Credit: *The Journal of Physical Chemistry Letters* (2023). DOI: 10.1021/acs.jpclett.3c03235

Feldspar is a ubiquitous mineral and makes up about half of the Earth's crust. In the Earth's atmosphere, feldspars play a surprisingly important role. Fine powder carried by air influences cloud formation. Water molecules adhere better to feldspar dust than to other particles. Tiny feldspar grains, floating in the atmosphere, thus become excellent nucleation seeds, where water molecules stick and freeze, eventually forming a cloud.

It is unclear why feldspar has this remarkable ability to bind water efficiently and enable cloud formation. Using a highly sensitive atomic force microscope, researchers at TU Wien have shown that the unique geometry of the feldspar surface provides the perfect anchoring point for OH groups of hydrogen and oxygen—and subsequently for water.

The study is published in *The Journal of Physical Chemistry Letters*.

Images with atomic resolution

"Researchers were considering several ideas why feldspar is such an effective nucleation seed," says Prof. Ulrike Diebold from the Institute of Applied Physics at TU Wien, who led the project. "It could be due to potassium atoms contained in feldspar, or perhaps certain defects in its crystal structure."

To find out, TU researchers used a sensitive atomic force microscope. In this microscope, the surface of the crystal is scanned with a fine tip point-by-point. The force between the tip and the surface produces an image with high resolution, where the position of each atom can be precisely determined.

"We placed a piece of feldspar in the microscope's vacuum chamber and split it in half to obtain a pristine and clean surface," says Giada Franceschi, the study's first author. "We were puzzled by the results: The images of the surface looked different from what common theories had predicted."

An optimal connection: The hydroxyl layer

The cause was quickly found: Tiny water inclusions in the rock were the culprits. When the stone is broken apart, a little water vapor is released. This vapor attaches to the freshly split surface, and the water molecules break apart, forming hydroxyl (OH) groups. "Under the microscope, you don't see the feldspar surface itself but a surface covered with hydroxyl groups," explains Giada Franceschi. "In nature, the feldspar surface is also covered with such a hydroxyl layer."

Due to the geometry of the feldspar crystal, these hydroxyl groups are positioned in a way that makes them ideal anchoring points for water molecules. Water molecules can dock to the hydroxyl groups like building blocks that fit together precisely. Thus, the hydroxyl layer forms the perfect connection between feldspar and the water that attaches as ice. "The bond is established very easily and quickly, and it is also very stable," says Ulrike Diebold. "To remove the hydroxyl layer from feldspar, one would have to heat it to high temperature." Computer simulations also support this finding.

The results provide insight into why specific crystals in our atmosphere are particularly well-suited as cloud-forming nucleation seeds. Especially in the face of climate change, it is important to understand the physics of cloud formation better. And sometimes, as the research project at TU Wien shows, one has to delve deep into the world of atoms.

More information: Giada Franceschi et al, How Water Binds to Microcline Feldspar (001), *The Journal of Physical Chemistry Letters* (2023). DOI: 10.1021/acs.jpclett.3c03235

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