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Stories of mineral transformation

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Chemical, physical and biological forces all act to weather minerals. Rebecca Lybrand explores how mineral transformations are ubiquitous in the environment and in our daily lives.

Weathering is an intricate process that reflects the journey of a mineral. It is caused by mineral interactions with water, ice, acids, salts, plants, animals and microorganisms, and physical changes in the environment such as temperature[1]. Mineral weathering has societal importance, with links to the cycling of carbon and nutrients, and even the safe geological storage of spent nuclear fuel[2]. It is equally crucial when identifying strategies for preserving cultural heritage artefacts – such as buildings, statues and medieval stained glass – that are also subject to weathering by water and microbes alike.

Mineral weathering is present in our daily environments and takes on a variety of forms. Some minerals weather by dissolving completely in a solution, as we see when stirring a spoonful of table salt (sodium chloride, NaCl) into a glass of water. Others transform into entirely new minerals by reacting with water, free oxygen, or atmospheric carbon dioxide that mixes with water droplets to form carbonic acid, another agent of chemical weathering. If you have ever noticed the reddish-brown rust that forms on a metal tool or an old bicycle left outside exposed to the elements, you have witnessed evidence for chemical weathering. Refined iron has reacted with oxygen and moisture in rain or the air to form a new mineral informally known as rust – an iron oxide comprised of iron and oxygen (that is, Fe_2O_3).

If we were to pick up a rock along a walk or kneel down to grasp a handful of soil, we would hold a complex and captivating microcosm in our hands. This becomes more intricate when focusing our view to a single sand-sized particle. Microscopic investigations of minerals reveal remarkable glimpses of a micro- to nanoscale world invisible to the naked eye. Mineral surfaces are peppered with evidence of weathering in the form of microfractures, cracks, pits, and sometimes the presence of clay minerals that appear as tubes, elongated ribbons, or even the plate-like pages of a book. One picturesque example is mica weathering, which serves as a natural and prevalent source of potassium to the terrestrial environment[3,4]. Mica, a sheet silicate group that includes biotite, weathers into flexible or brittle sheets with fan-like, frayed edges where weathering has disrupted the planes of its crystal structure at the atomic scale and released potassium to the environment from its interlayer spaces[5].

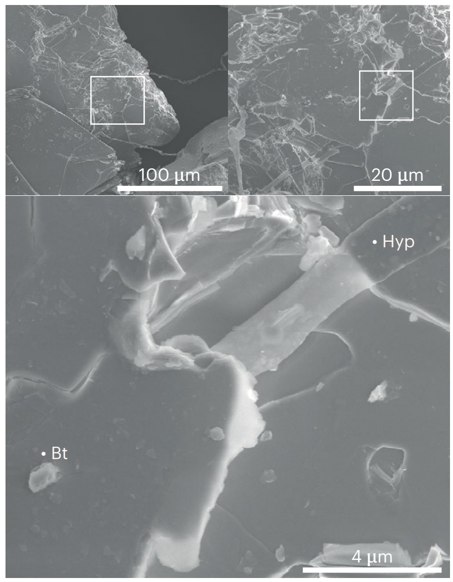

Fig. 1 | Evidence of biomechanical weathering as observed using a scanning electron microscope. The micrographs show a fungal hypha (Hyp) penetrating a surface layer sheet of biotite (Bt). Adapted from ref. 7, Springer Nature Limited.

Organisms also weather minerals. Trees physically weather rocks in search of nutrients or water through root wedging. The roots penetrate into cracks or fractures, grow larger, and mechanically widen the cracks, which eventually splits the rock apart into smaller and smaller pieces. Plant roots also secrete organic acids to indirectly dissolve, release, and access life-supporting elements from minerals, such as the indirect weathering of iron or magnesium from olivine, a mineral that is highly susceptible to weathering. Plant roots associated with soil fungi also directly mine elements such as calcium or phosphorus from minerals including apatite, a common group of phosphate minerals. Fungi forage through soil in search of nutrients or water by extending their filaments across particles of quartz, along the edges of biotite micas (Fig. 1), or through the surface layers of plagioclase feldspars. Fungi are even capable of producing new minerals – including oxalates, oxides, or carbonates – through biomineralization[6]. Bacteria can also etch or tunnel into minerals or basaltic glass grains to access nutrients; the same evidence for bacterial weathering has been detected at the depths of the sea, where bacteria tunnel into the volcanic glass of oceanic basalts, leaving behind signatures of life that may endure for millennia.

Weathering and transformation are therefore foundational to the biosphere, driving element cycling between the inorganic and organic realms. Our planet relies on the transformation of minerals, and ultimately so does our society.

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Competing interests

The author declares no competing interests.