

How does potassium help to understand the Earth's climate: On isotopes, phyllosilicates, and weather from millions of years ago

Carbon dioxide (CO₂) is one of the greenhouse gases. One of the key processes influencing the atmospheric CO₂ level is continental silicate rock weathering. When minerals contained in rocks break down due to the action of water, CO₂, and living organisms, they liberate calcium and other elements. Calcium is transported to the ocean, where it reacts with dissolved CO₂ coming from the atmosphere, forming carbonates that lock up CO₂. This process leads to the removal of atmospheric CO₂. One can say that this process acts as a natural thermostat. The warmer the climate, the more intense the weathering, and the more calcium is transported to the ocean. As a result, more CO₂ is locked up in carbonates. In the long term, this leads to climate cooling.

However, there is a lesser-known counteracting process called the “reverse weathering”. Part of the elements dissolved in seawater, such as calcium, magnesium, iron, and potassium, are incorporated into the structures of phyllosilicates forming on the sea bottom. This leads to CO₂ release to the atmosphere. The balance between weathering and reverse weathering plays an important role in the long-term regulation of the Earth's climate.

In recent years, a new proxy has been proposed to track the intensity of both these processes: measurement of potassium isotopes, or more specifically, measurement of the ratio of the rare ⁴¹K isotope to the more widespread ³⁹K. This ratio is by convention reported as δ⁴¹K. The more of a rare ⁴¹K a substance contains relative to a standard, the more positive its δ⁴¹K value. Potassium is a good weathering tracer because it is involved in both continental weathering and reverse weathering in the ocean. Interestingly, despite the fact that rivers provide potassium to the ocean with a relatively low δ⁴¹K value, the δ⁴¹K of seawater is considerably greater. At the moment, this discrepancy is explained by the preferential incorporation of the light ³⁹K into the marine clay mineral structures, leaving the heavy ⁴¹K in the seawater, which results in its high δ⁴¹K value.

The project aims to enhance our understanding of processes that lead to changes in the potassium isotope composition during its geochemical cycle. A series of experiments involving various clay minerals is planned, with special emphasis on those varieties capable of adsorbing large quantities of potassium. Both adsorption (potassium uptake) and desorption (potassium release), as well as the associated changes in potassium isotope composition, will be studied. Natural soil, weathering profile, and marine sediment samples will also be investigated to constrain their mineralogical and isotope composition. Additionally, a set of quantum mechanics computer calculations will be performed to investigate how various clay mineral structures incorporate potassium isotopes.

The goal of the project is to get a clearer picture of changes in potassium isotope composition during its geochemical cycle. This will allow for a better employment of δ⁴¹K as a weathering intensity tracer in Earth's geological past. This, in turn, will allow a better understanding of changes in the atmospheric CO₂ levels in the past and of possible future climate changes.