

Shrinking mountains

Rocks of the Earth

A cool climate may be to blame for eroding some of the world's highest summits in the past.

The silent peaks of the Himalayan mountain range pierce the cloudy Asian sky. You could be fooled into thinking this is a peaceful place, but mountains are endless construction sites. Continental plates collide and force the Earth's crust upwards while, at the same time, erosion counteracts this process by slowly weathering the planet's surface. Rivers, glaciers and landslides scour through the bedrock and move sediment back down to lower ground.

What exactly the forces at play in mountain building and destruction are is controversial. Scientists on one side argue the main influence on high altitude erosion is tectonics, which is constantly heaving sediment to the surface. Others, such as [Peter Molnar and Philip England](#), suggested that climate is a bigger factor in the long term, wearing away mountain peaks.

Now a new study by Frédéric Herman of the University of Lausanne, Switzerland, and collaborators shows for the first time that erosion rates can speed up when the global temperature drops. "This study gives a unique contribution to one of the most intriguing debates in Earth Sciences today," says Vivi Pedersen at the Department of Earth Science, University of Bergen, who was not involved in the study.

Swings and roundabouts

The Earth's climate naturally fluctuates between warm and cold periods. A strong cooling trend began six million years ago and, using sediment records, scientists observed a rapid increase in erosion rates around that time. In particular, since the onset of the Quaternary period some 2.5 million years ago, erosion increased dramatically by at least a factor of two.

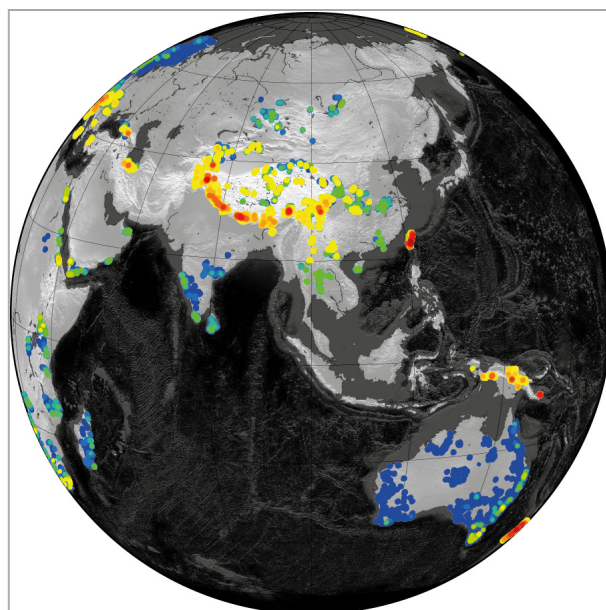
But, until now, no-one was able to show why exactly that happened. Sudden changes have often been put down to capricious tectonic movements, but high rates of erosion followed a pattern that suggested something else. At latitudes between 30° and 50°, where glaciers and large ice sheets would have iced the continents, erosion increased significantly. This led scientists to consider the role of climate, and, particularly, the role of glaciers in mountain building and destruction.

Hot rocks

Herman and his team used the thermal ages of rocks – a technique known as [thermochronology](#) – to determine past changes in erosion rates. As rocks move away from the heat of the Earth's core, the minerals begin to cool and change. The scientists used the natural abundance of a mineral's radioactive isotope and its decay products to find how fast the rock moved towards the surface and, therefore, its age. The closure temperature – when the mineral has cooled



The glaciers of southern Tibet carve valleys in the Himalayan mountain range. (Credit: Amos Aikman)



Erosion rates between 2 Myr ago and 0 Myr ago, as determined by Herman et al. (2013). The colours represent varying degrees of erosion rate, from about 0.01 mm/yr (blue) to 7 mm/yr (red). Along mountain ranges such as Himalayas and the New Zealand Southern Alps the rates of erosion during this time period were up to four times higher than 6–4 Myr ago. (Credit: Frédéric Herman)

enough to stop isotopes diffusing out of the rock – is used as the starting point. A cooling history can be found by dating two minerals (apatite and zircon) with different closure temperatures in the same rock. Age is then converted into erosion rates using a thermal model.

Map the world

The ages were then matched together in a global set. Global patterns of erosion emerged in separate plate-tectonic regions. "We found [that] erosion rates are sensitive to changes in climate even though tectonic activity always has some control," says Herman.



View of one of the peaks of the Southern Alps. (Credit: Frédéric Herman)

Eighteen thousand rock ages were used in the project – a huge job. “The course of one PhD usually identifies around 30 rock ages so we benefited from a large number of people’s work,” says Herman.

“A global signal requires a global cause, and the strong correlation found with global climate change shows that cooling is a very good candidate for the causing mechanism,” says Pedersen. “This study gives persuasive evidence for a strong link between highly variable cold climates and erosion rate, especially linked to glacial and periglacial processes.”

Pointing to glaciers as a cause of the erosion makes sense: glaciers can scour relatively flat topography into a rugged, jigsaw-like landscape within several thousand years. The rock currently on the surface of the fjords in the New Zealand Southern Alps, for example, used to lie two kilometres deep just 2.5 million years ago – a rapid

change in geological terms. However it’s not just glaciers that can have an influence. These Southern orogens – belts of the Earth’s mountainous crust – receive high amounts of rainfall, which can trigger landslides and add to the erosive action.

Missing years

But the climate versus tectonic debate does not stop here. Thermochronometry is based on the idea that a rock’s age can be converted into an erosion rate. The rocks must have been moved a couple of kilometres through the Earth before a rock age can be taken, a process that only occurs in areas where there is enough tectonic activity, such as the Alps, Patagonia and Himalaya.

Philippe Steer, who [used a different method](#), found erosion increased by a factor of 20 during the past five million years. Even with such a huge increase, the total erosion remains too small to be detected by the technique used by Herman and his colleagues, so this study was restricted to certain parts of the world only.

“We don’t know every cycle and are only seeing one part of the signal. Therefore this study is just the tip of the iceberg,” says Herman. “We are now developing techniques to isolate shorter timescales to, say, 100,000 years.”

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References

- Herman, F. et al.: [Worldwide acceleration of mountain erosion under a cooling climate](#), *Nature*, 504, 423–426, 2013
- Molnar P. and England P.: [Late Cenozoic uplift of mountain ranges and global climate change: chicken or egg?](#), *Nature* 346, 29–34, 1990
- Steer, P. et al.: [Bimodal Plio-Quaternary glacial erosion of fjords and low-relief surfaces in Scandinavia](#), *Nature Geosci.* 5, 635–639, 2012

A glimpse of Mars’ early history

Space and the Earth

Finding increasing evidence of rocks previously thought to be non-existent on Mars sheds new light on the composition and early evolution of the planet.

[Termed the Goldilocks Planet](#) because of its ideal distance from the sun, which allows the planet to have liquid water on its surface, the Earth is also the perfect size to have maintained plate tectonics over the past 4,600 million years. [Mars was likely too small to develop plate tectonics in its early years](#), cooling too quickly to maintain the hot core needed to power large-scale motions on the surface of the planet. Tectonics are the key to the variety of rocks we have on Earth: the tectonic system works as a giant conveyor belt that transports elements from deep within the planet up to the surface and back again. Mars, without the ability to maintain a tectonic cycle,

was left with a [largely basaltic composition](#). So, recent articles by [Wray et al. \(2013\)](#) and [Carter and Poulet \(2013\)](#) describing Martian rocks containing large amounts of iron-rich feldspar (a group of aluminium silicate minerals not commonly found in basaltic rocks) are unexpected and exciting.

In both studies, the researchers used data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on the Mars Reconnaissance Orbiter to identify the feldspars. Usually, feldspar is undetectable by CRISM, unless there are small amounts of metal such as iron within the mineral structure. CRISM detected very weak absorptions in the wavelength range typically associated with iron, but not strong enough to indicate the presence of iron-rich minerals like olivine and pyroxene common in basalt. Because of