meteorites, making formation by degassing magma more likely than formation by aqueous weathering.

For the clay minerals to have formed from magmatic processes alone, much of the ancient crust of Mars must have been emplaced as basaltic lava flows, accompanied by degassing of significant amounts of volatile material. The latter constraint is probably met, since both the Mars meteorites[5–6] and thermal modelling[7] imply up to several weight per cent of water in martian parent magmas.

The broad composition and emplacement mechanisms of the ancient crust are less constrained, owing to its degraded nature and other preservation issues. For example, in the Valles Marineris rift system, an exposed stratigraphic section about 10 km thick is interpreted as layered flood basalts[8], in line with the hypothesis. But because this rift is located on the side of the Tharsis rise — the largest volcanic–magmatic complex in the solar system — it is unclear if this section is representative of the broader ancient crust of Mars. Nevertheless, high heat-flows early in the martian history[7] imply that extensive volcanism is a possibility.

Only *in situ* measurements of clay minerals on Mars can provide conclusive proof of their origin. In the near future, two rovers on Mars — Opportunity, landed in 2004, and Curiosity, in 2012 — may provide such direct evidence from two locations that bear phyllosilicates: Endeavour Crater and Gale Crater.

If it turns out that formation of the clay minerals on Mars from degassing magma, as proposed by Meunier and *et al.*[4], was a pervasive process, then early warm and wet conditions and extensive crustal reservoirs of water were not necessary to form the clay minerals. Such a result would imply that early Mars may not have been as habitable as previously thought at the time when Earth's life was taking hold. ❐

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BIOGEOCHEMISTRY

Riverine carbon unravelled

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Rivers carry significant quantities of terrestrial carbon towards the ocean. Much of this carbon comes from terrestrial vegetation and soils. But some originates from carbonaceous rocks, worn away by erosion. As such, rivers serve as a meeting point for the biological and geological carbon cycles. The extent to which these cycles interact is uncertain, but will be affected by the degree to which biogenic and petrogenic sources contribute to the complex mix of river carbon.

Unfortunately, unravelling the source of riverine carbon is difficult. Plant-specific biomarkers have rendered components of the young biogenic carbon pool relatively easy to detect. But establishing the origin of the older, chemically complex pool, within which petrogenic carbon falls, has proven tricky.

Brad Rosenheim and Valier Galy (*Geophys. Res. Lett.* http://doi.org/jcd; 2012) offer a novel radiocarbon-based approach for assessing the source of riverine particulate organic carbon. They use suspended sediments collected from Narayani River — one of the largest Himalayan tributaries to the Ganges during the monsoon season — as a test bed for their approach. The technique hinges on the linear heating of sediments from laboratory temperatures up to 1,000 °C, and the radiocarbon analysis of carbon dioxide collected along the way.

They detected a broad spectrum of radiocarbon ages, ranging from the very young to over 30,000 radiocarbon years in age, each corresponding to a different component of the organic carbon pool. Using a Gaussian decomposition model to pick out different fractions of this pool, they estimate that petrogenic carbon accounted for 0.067% of the particulate carbon in sediments collected in 2005, in line with previous suggestions, and 0.17% in those collected in 2007.

To get a feel for the consistency of this age spectrum across settings, Rosenheim and Galy compare their findings to radiocarbon data collected in a similar fashion from the Mississippi–Atchafalaya river system. According to their analysis, the fast-flowing waters of the Narayani, which cuts through old, carbonaceous bedrock, yield a much broader spectrum of radiocarbon ages than the relatively slow-moving waters of the Mississippi–Atchafalaya system.

The Narayani River probably plays just a small role in the global carbon cycle. However, the findings point to a potentially significant difference in the age spectrum of carbon delivered to the oceans by small mountainous rivers and their large meandering counterparts.

ANNA ARMSTRONG