It may thus be that the long-term response of clathrates to anthropogenic warming needs further investigation[10]. This point is of particular importance considering evidence for widespread methane leakage from the sea floor in both the Arctic Ocean[11–13] and the northern margin of the Atlantic seaboard of the USA[14]. These releases may be related to the warming of ocean waters associated with anthropogenic climate change.

Bowen *et al.*[2] have identified an initial, large pulse of carbon emission preceding the massive carbon release associated with the PETM. If this second carbon release reflects a feedback mechanism, there may be disturbing implications for the long-term consequences of the current anthropogenic warming. ❐

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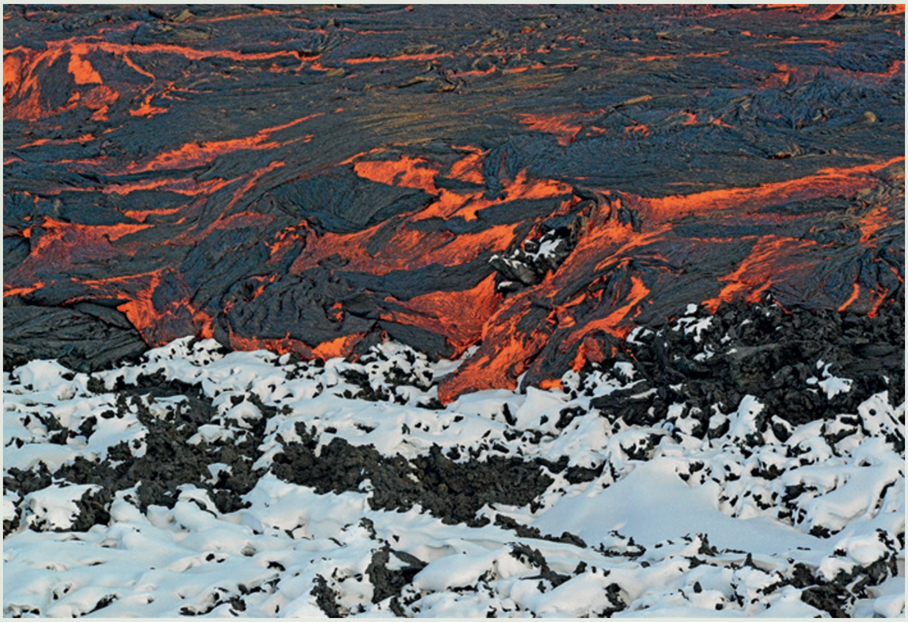
VOLCANOLOGY

Fire meets ice

In cold regions, hot lava from erupting volcanoes meets snow and ice. This potentially dangerous mixture can lead to rapid flooding. Indeed, in Iceland, an island rich in both volcanoes and frozen water, glacial outburst floods are the most frequently occurring volcano-related hazard. As many as 500 volcanoes on Earth are covered with snow and ice, at least seasonally. Many of these are far away from human settlements, but others pose a potential threat to the population living near their flanks.

Nevertheless, the movement of lava flows across snow and ice has rarely been observed in detail. Benjamin Edwards and colleagues now report quantitative observations from the 2012–2013 eruption at Tolbachik volcano on the Kamchatka Peninsula, Russia. Their work reveals that two different kinds of lava — jagged blocky 'a'a lava and smooth-flowing pahoehoe lava — interact with snow in very different ways (*Nature Communications* **5,** 5666; 2014).



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Specifically, the observed lava flows moved over the top of the snow, beneath it and even through fractures in the snow cover. Observation pits dug in front of the advancing lava flows allowed the researchers to identify how lava moved through the snow and how much melting was happening at the lava–snow interface. It turned out that blocky 'a'a lavas advanced on top of the snowpack with melt water accumulating beneath the lava flow. Pahoehoe lavas, by contrast, advanced under or inside the snowpack, allowing melt water to interact with the lava and producing distinctive lava textures.

In contrast to earlier ideas, an insulator layer between 'a'a flows and the underlying snow is not required. Instead, the rapidly advancing lava develops a thin chilled crust at the base that provides significant thermal insulation. Despite this insulation, however, 'a'a flows melted through the entire underlying snowpack at Tolbachik within 24 hours.

Pahoehoe lavas, on the other hand, were observed to form multiple smooth-surfaced, bulbous lobes of lava inside the snowpack, with the surrounding snow remaining rigid and breaking up into blocks. Each lobe gradually filled with lava, and inflated to maximum dimensions of around one metre before fracturing to produce a new lobe. The snow domes that were forced upwards by the lava melted within hours, leaving behind solidified lava with characteristic textures and shapes.

Encounters between fire and ice are necessarily ephemeral, but the locations of their rendezvous are marked by characteristic field evidence. Looking for these traces, we may be able to identify ancient lava–snow interactions on Earth, or areas of lava and ice contact on Mars.

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