CLAUDE BOUTRON

Figure 1 | Where ice and water meet. Reconstructions of atmospheric mercury deposition over Antarctica during the past 670,000 years show episodes of enhanced deposition during the coldest periods of glacial climate. Jitaru and colleagues suggest that an increased production of bromine radicals triggered a series of reactions that led to mineral dust scavenging mercury from the atmosphere[2].

ancient depletion events as well. Their results indicate that the Hg^{2+} species was an important component of the total mercury during these deposition periods. They suggest that during the coldest phases of past glacial periods, increased fallout of sea salts over Antarctica[9] and subsequent photochemical reactions led to an increased production of bromine radicals. Under cold enough conditions, the bromine–mercury reaction produces a stable intermediate, $HgBr_2$. This intermediate molecule should be efficiently scavenged by the dust (also higher relative to interglacial periods), which would then carry the mercury to the Antarctic snow cover. Jitaru and colleagues present a simple model that shows that the increased scavenging of mercury during the dustiest periods explains the high glacial mercury deposition during cold episodes, relative to the Holocene (~10,000 years ago to present day).

However, it is not yet possible to verify the operation of these processes over glacial Antarctica, as the reactive bromine species are not preserved in the glacial ice. Thus, although this is an elegant theory, the ice-core results alone are unable to provide a complete picture of ancient mercury-cycling in the atmosphere.

Nevertheless, Jitaru and colleagues[2] provide interesting insights into the interplay between bromine–mercury chemistry and elevated mineral-dust load, which seems to favour polar regions as a global sink for atmospheric mercury, at least during glacial periods. ❐

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MARINE GEOPHYSICS

Where there's smoke there's fire

Seafloor vents spewing mineral-rich plumes of hydrothermal fluid — termed black smokers — can persist at mid-ocean ridges for decades or longer. Earthquake data indicate that ongoing magma injection may determine their locations.

Maya Tolstoy

Black-smoker hydrothermal venting, which occurs along mid-ocean ridges in the world's oceans, results in significant heat and chemical exchange between Earth's crust and the overlying water. Black-smoker vents provide nutrients for extraordinary chemosynthetic biological communities, expanding our knowledge about how life may exist on Earth and elsewhere. Black smokers are generally associated with loss of heat from a magma body within the oceanic crust: as sea water percolating through the crust approaches the magma, it is heated and laden with minerals, and subsequently returns to the sea floor. Venting sites are common along the global chain of seafloor volcanoes, but the factors influencing their location remain elusive. On page 509 of this issue, Wilcock and colleagues[1] suggest that black smokers may occur at sites where the magma chamber is being actively recharged.

The discovery of high-temperature hydrothermal vents in 1977 (ref. 2) opened a new chapter in deep-sea exploration and sparked a search for more black smokers. So far, only about 20% of the global mid-ocean-ridge system has been surveyed for indications of venting[3], and only a fraction of these sites have been visually imaged. Global water-column mapping of hydrothermal plumes reveals a pattern of increased density of vent sites with increased rates of seafloor spreading at mid-ocean ridges[3,4]. Because magma supply varies in proportion with spreading rates, this pattern contributes to a growing body of evidence for the 'magmatic budget hypothesis' (for example, refs 5, 6), which proposes that magma supply is the primary control of global vent distribution.

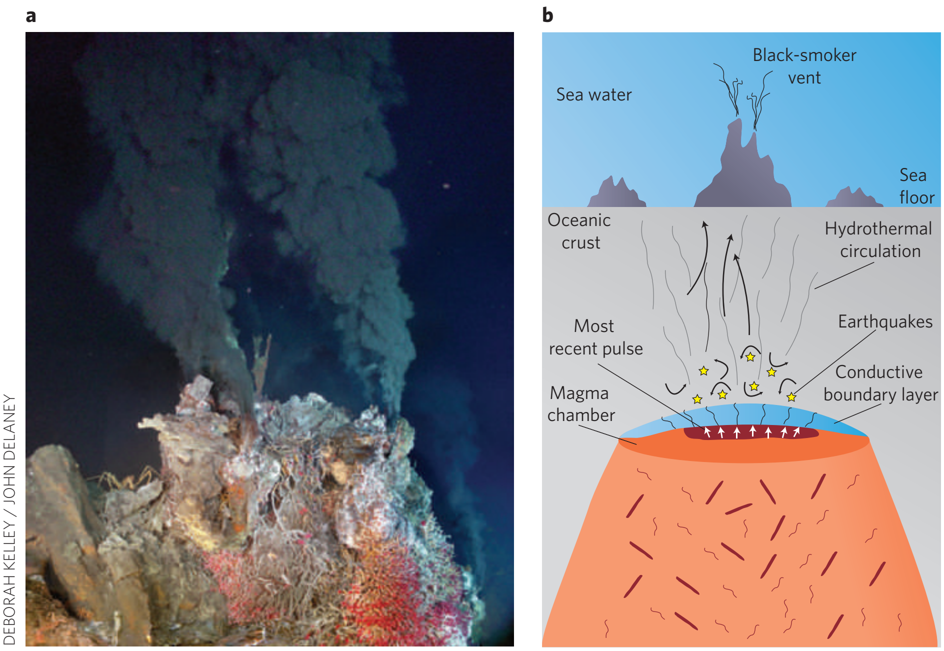

Figure 1 | Spewing smoke. **a**, The photograph depicts a chimney called Sully, which vents fluids at 360 °C and is located in the Main Endeavour field of the Juan de Fuca ridge in the Pacific Ocean. **b**, Schematic sketch (not to scale) showing how cracking induced by ongoing magma injection may help maintain a thin conductive boundary layer at the top of the magma chamber, thereby facilitating hydrothermal venting.

Seismic imaging has shown that black-smoker vents are likely to be preferentially situated above magma bodies that have recently received a fresh supply of melt[7]. Thermal modelling has also indicated that magmatic recharge may be critical for maintaining long-term hydrothermal venting[8,9]. The idea that continued heat input is necessary to prevent the magma body from freezing is compelling, but the mechanism by which this might lead to sustained venting has been less well defined.

Seeking to better understand the processes involved in hydrothermal venting, Wilcock and colleagues[1] analysed micro-earthquake data from the Endeavour segment of the Juan de Fuca ridge in the Pacific Ocean, a site that has experienced long-term hydrothermal activity. Earthquake focal mechanisms, which provide information about the nature of motion during an earthquake, can be used to understand the local stress field. Based on data for 170 earthquakes, the researchers documented linear patterns of compression and extension parallel to the mid-ocean ridge. Their calculations suggest that these patterns are consistent with deformation above a magma lens that would result from magma injection.

Because of the small magnitude of the earthquakes and instrumental challenges — usually, seismometers are simply dropped over the side of a ship to a rocky seafloor — good focal mechanism data have been rare. This study used data acquired by a new array of 'corehole' seismometers (see online Backstory[10]) developed at the Monterey Bay Aquarium Research Institute. The sensors were inserted into holes drilled into seafloor lava, which resulted in excellent seafloor coupling and reduced noise from ocean currents[11].

The conductive boundary layer separating the magma from the circulating fluids needs to be relatively thin, on the order of a few to tens of metres, to maintain the high heat fluxes observed at black-smoker vents[9]. However, as the magma chamber lid freezes owing to cooling and crystallization, and cracks above the chamber get clogged from mineralization, the boundary layer thickens. This process has long plagued modellers trying to understand how the high heat fluxes can be maintained through time. Wilcock and colleagues[1] propose that stresses due to the continuing supply of new magma push the lid of the magma chamber up, allowing new cracks to form in the lid and preventing the thickening of the boundary layer (Fig. 1). Magmatic recharge can thus help sustain the vent field beyond simply supplying more heat.

Of course, ongoing magma injection does not explain the presence of sustained venting in the absence of a crustal magma body, or eruptions where no venting is observed. Also, high-temperature venting is sometimes absent from areas where melt-rich magma chambers are known to exist, but is observed in regions where seismic data reveal melt-poor[4] chambers. It is possible that imaging techniques have been unable to detect deeper magma bodies or that the fraction of melt in a magma chamber is not necessarily reflective of whether magma injection is presently occurring. Nevertheless, it seems likely that there are other factors contributing to the location and longevity of hydrothermal vent fields.

For example, tectonic stresses associated with seafloor spreading and/or segmentation may have a significant role in determining zones of high permeability where fluids are able to enter or leave the crust[6,12,13]. Perhaps sustained venting requires both ongoing replenishment of magma and close proximity to a tectonically induced zone of high permeability. Wilcock and colleagues address how hydrothermal processes are sustained once the fluid is at mid-crustal level, but not how it gets there or how it leaves.

Nevertheless, the explanation provided by Wilcock and colleagues[1] for the long-term stability of vent sites, as well as for the unusual distribution of focal mechanisms observed, is elegant. If their theory is correct, the presence and duration of hydrothermal venting may act as a guide to locations of ongoing magma replenishment. The results highlight the importance of continued long-term monitoring at mid-ocean ridges to understand these complex and dynamic processes. ❐

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