Volcanoes past and present

Volcanism and Global Environmental Change

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Nearly every day, at least one volcano on Earth belches out some combination of gases, ash and lava. The effects of these eruptions are typically local, rarely felt beyond the immediate vicinity of the volcano. But every now and then, a powerful eruption is capable of altering worldwide climate and environmental parameters. *Volcanism and Global Environmental Change* brings together a series of articles written by experts from around the globe to highlight current understanding, or lack thereof, of the links between giant volcanic eruptions and our environment.

The reader is taken on a journey from the deep Earth to the surface and atmosphere, as the book describes the path of heat and material from deep inside the planet to the places where humans live. At the core–mantle boundary, reservoirs of thermally and chemically distinct material are thought to generate hot plumes that well up through the Earth. Such plumes may trigger melting in the shallow mantle and voluminous eruptions of lava at the surface. The recycling of cold, dense crust back into the Earth at subduction zones also generates volcanism, though generally on a smaller scale. Both types of eruptions release gases that, depending on the altitude of their ejection, have the potential to alter climate and in turn the biosphere, possibly even triggering mass extinctions.

Super-eruptions can be defined by the explosivity of the eruption or the amount of material erupted, but the latter is most easily identified in the geologic record. The most extreme examples of super-eruptions are those that lasted for one to a few million years and brought a million or more cubic kilometres of lava to Earth's surface to form large igneous provinces (LIPs); these giants are the focus of several chapters. Links between LIPs, climate change and mass extinctions are increasingly — if tentatively — being made. Previously, it was unclear whether LIPs could drastically alter global climate because these provinces were thought to form largely from effusive eruptions that only injected gases and aerosols into the troposphere, where they would be rapidly washed away. Plus, the amount of climate-altering gases in the mantle source for the lavas was thought to be small. It now seems that LIP eruptions were probably more explosive than previously thought, capable of injecting aerosols and gases into the stratosphere, where they can affect global climate. And although the subduction of carbon-rich rocks could enrich the deeper Earth with carbon, the source of the climate-altering gases need not be the mantle alone. The intrusion of magmas into carbon-rich sediments and rocks at the surface can also trigger metamorphism-induced release of vast quantities of CO_2. The implication is that the environmental impact of an LIP eruption will vary drastically depending on location. We must study each on a case-by-case basis.

The Siberian Traps, emplaced about 252 million years ago coincident with the End-Permian extinction, is one of the best-studied examples of an LIP and widespread environmental upheaval. The eruption of the Siberian Traps released climate-altering gases, particularly SO_2, which can trigger short-term cooling, and CO_2, which leads to longer-term global warming. The volcanic gases would also have caused acidification in the ocean and land surfaces, and the pattern of extinction during the End-Permian crisis is consistent with rapid, extreme warming and ocean acidification. But correlation is not necessarily causation. A key outstanding question, we learn, is one of timing. Poor age constraints on both the timing of the eruption — a lack of easily dated zircons in the basaltic lavas necessitates a reliance on less precise means of dating — and the extinction make it difficult to definitively link various eruptive stages with environmental change.

The ancient, giant events garner much attention in the book, but this discussion is nicely balanced by descriptions of smaller, more recent episodes of volcanism, which can also influence climate. Although the one to two year periods of cooling associated with eruptions such as Mount Tambora in Indonesia in 1815 and Mount Pinatubo in the Philippines in 1991 are virtually unidentifiable on geological timescales, these periods are significant for humans. In particular, the impact of volcanic halogens, such as chlorine and bromine, on the atmosphere is emerging as an important field of investigation. Previously assumed to be passive, we now realise these gases can trigger ozone-depleting reactions. The full impact of recent eruptions is blurred by the dramatic influence of human activities on the ozone layer. However, thanks to restrictions on chlorofluorocarbons use since the 1980s, ozone levels are recovering. We should be able to more accurately constrain the links between volcanism and ozone depletion in the future.

Our capacity to observe eruptions has been greatly enhanced by satellite data, even though no existing satellite was created with this purpose in mind. Rather, satellites launched since the 1970s to examine weather systems and sea-surface temperatures turned out, serendipitously, to be well suited for monitoring ash plume evolution and volcanic gases, too. There are no plans to launch satellites designed specifically for volcanic monitoring in the near future, we are told, but new monitoring techniques, such as unmanned aircraft and automated vehicles, are emerging. One unique and underused resource is photographs of eruption plumes from above, taken by astronauts aboard the international space station. A NASA image of the 2009 Russian Sarychev eruption plume breaking through clouds provides a breath-taking example.

The book's main strength lies in the combination of articles that tie together a wealth of observations from fields including volcanology, palaeontology and ecology, as well as atmospheric and climate science. The generally easy-to-follow narrative, with carefully worded introductory and summary sections in every chapter, means that non-specialists, too, could gain valuable new insights without having to understand the details of the discussion. One take-home message is that there is still so much we don't know about "the ultimate geologic hazard". But even though there are currently few firm answers, the outstanding questions and directions for future research are described nicely. We are left to ponder whether periods of increased carbon subduction could lead to enhanced CO_2 release from volcanoes, or whether ash deposition could trigger CO_2 drawdown due to enhanced erosion of these friable deposits. The book is motivational and the reader is left with the impression that this is an exciting and growing field. ❐

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