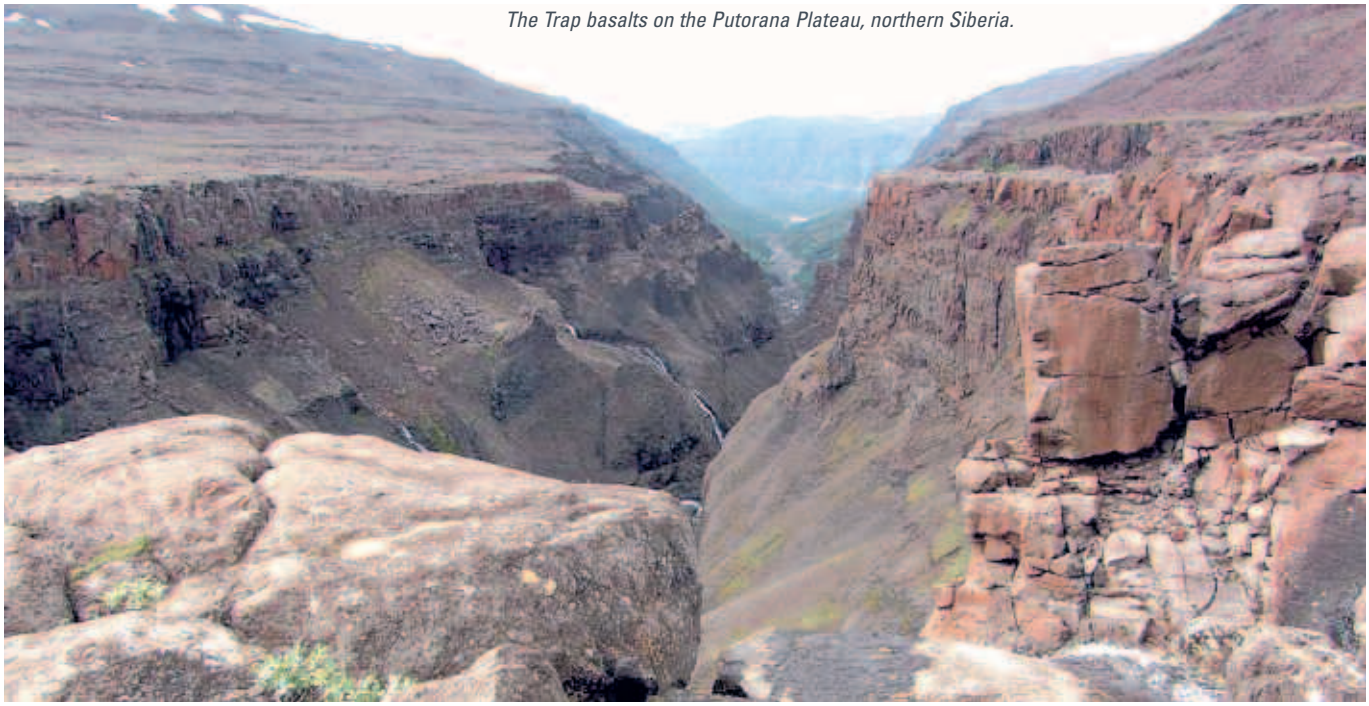
# MASS extinctions



The Trap basalts on the Putorana Plateau, northern Siberia.

NHK (Japanese TV)

Meteorites have made a big impact on planet Earth, but **Andy Saunders** and **Marc Reichow** believe that when it comes to mass extinctions, there could be another candidate: flood basalt eruptions.

Earth history has been punctuated by several mass extinctions, when nearly all life forms on our planet were wiped out. What causes these catastrophic events? The popular view is that they are caused by the cataclysmic impacts of large meteorites. However, there is a growing realisation that the causes may lie closer to home, and be linked to huge volcanic eruptions – flood basalt eruptions – that bring a cocktail of gases from deep inside the Earth and cause widespread and catastrophic global pollution.

The idea that meteorite impacts caused mass extinctions has been in vogue over the last 25 years, since Louis Alvarez's research team in Berkeley, California, published their work about an extraterrestrial iridium anomaly found in 65-million-year-old rocks at the Cretaceous-Tertiary boundary – the time of the dinosaurs' demise. The iridium, and the presence of 'shocked quartz' – essentially, grains of sand that have had their crystal lattice disrupted by a violent shock wave – could best be explained by a large meteorite hitting the Earth. Subsequently, scientists discovered the impact site, a 180km diameter crater, in Chicxulub, Mexico.

Impacts are suitably apocalyptic; they are the stuff of Hollywood. It seems that every kid's dinosaur book ends with a bang. But are they the real killers, and are they responsible for all, or indeed any, mass extinctions? There is scant evidence of impacts at the time of other major extinctions, for example, at the end of the Permian, 250 million years ago, and at the end of the Triassic, 200 million years ago. Certainly, any evidence that has been found does not seem large enough to have triggered an extinction at these times. It would appear that other mechanisms are involved.

As suggested more than a decade ago by Vincent Courtillot, flood basalt eruptions provide an alternative 'kill mechanism'. These *do* correspond with all main mass extinctions, within error of the techniques used to determine the age of the volcanism. Several flood basalt provinces: the Emeishan Traps in China, the Siberian Traps in Russia, the Central Atlantic Magmatic Province in Africa and the Americas, and the Deccan Traps in India, coincide with four of the largest known mass extinctions (late-Permian, end-Permian, end-Triassic, and end-Cretaceous, respectively). This correspondence between volcanism and mass extinctions is very unlikely to be pure coincidence.

What makes flood basalt eruptions special? Typically, they are high-volume (literally, a flood), effusive eruptions, and individual eruptions may persist for years or even decades. Successive eruptions entomb the landscape beneath thick flows of basalt, in places many kilometres deep. When they eventually weather away, the flows produce a step-like profile and hence the word 'traps', from the Scandinavian, *trappe*, or steps. Flood basalt eruptions are quite different from

explosive volcanic eruptions like Pinatubo in 1991, or Krakatau in 1883, which although spectacular, are short-lived (lasting hours or days). The products of these explosive eruptions may remain in the atmosphere for a few months or at most a couple of years. Flood basalt eruptions pump out lava and a cocktail of gases, including sulphur dioxide, carbon dioxide and halogens, for several years or decades, creating persistent atmospheric pollution. The masses could be prodigious, with a single 1000km$^3$ eruption emitting 10,000 megatonnes (mt) of sulphur dioxide and 25,000mt of carbon dioxide. Some flows may be more than ten times this size; and an entire flood basalt province, such as the Siberian Traps or Deccan Traps, is built from many hundreds of such eruptions. To put these masses into perspective, a 1000km$^3$ lava flow would cover the area of Leicestershire to a depth of almost 400 metres; and the 1990 global production of sulphur dioxide from burning fossil fuels and industry was about 150mt.

In collaboration with Anthony Cohen, Steve Self and Mike Widdowson at the Open University, Malcolm Pringle at MIT, and international collaborators in Russia and China, we received a NERC grant to study the Siberian Traps. We want to map the extent and duration of this eruption, which took place 250 million years ago and coincides with the end-Permian mass extinction, and estimate its environmental impact.

The Siberian Traps are the largest known continental flood basalt province. It would appear, however, that the Traps are much more extensive than was originally thought. The outcrops shown on most maps form only part of the province, and large amounts of basalt occur beneath the West Siberian Basin and in the Urals Mountains. Samples of these basalts will be dated to see if they really are part of a much more extensive province, and to determine the duration of the activity. The material we have obtained will also be analysed using a range of geochemical techniques to determine their origin and affinities to the well-documented sections in Noril'sk, in northern Siberia.

The end-Permian mass extinction, about 250 million years ago, was the largest known, killing a large proportion of plant and animal species both on land and in the sea. It was also rapid, occurring over a period of less than a few hundred thousand years, and possibly much faster than this, but our knowledge is limited by the resolution of the dating techniques. The extinction coincides, within the error of the dating methods, with the volcanic activity. However, the big question is how the volcanism led to the mass extinction. Mere release of carbon dioxide, leading to global warming, is unlikely to be the whole story – the rate at which the gases were released into the atmosphere was too low. Release rates were – perhaps worryingly – a fraction of the current carbon emissions from human activity. Possibly, sulphur aerosols high in the atmosphere triggered volcanic winters, devastating plant life, and slowing the rate at which plants could capture carbon. This in turn could allow carbon to accumulate in the atmosphere leading to longer-term global warming.

Measuring how much gas was released during these eruptions 250 million years ago is a considerable challenge. We will study microscopic bubbles of melt trapped inside crystals in the basalts to estimate the original gas contents of the erupted lava. Using these data we hope to be able to assess the amount of sulphur dioxide released during eruption, and whether or not this may have caused climatic havoc, wiping out nearly all life on Earth.

From these data we hope to develop the links between the volcanic activity and mass extinction. If we can show, for example, that the full extent of the Siberian Traps erupted at the same time, we can be confident that their environmental effects were powerful. Understanding the causal links will be more challenging, but the system has resonance with current climate change. If we can understand the vulnerability of the past Earth system during these times of extreme stress, this may help in the understanding of the present, developing climate changes.

## Do meteorites cause flood basalt eruptions?

The coincidence between the meteorite impact site in Mexico, flood basalt eruptions in India and a mass extinction 65 million years ago has led to the suggestion that the meteorite triggered both the volcanic activity and the extinction. Scientists have carried out computer simulations to evaluate whether impacts can generate volcanic activity. However, there is no volcanism at the impact site in Mexico, and arguments that the impact triggered shock waves that generated volcanism on the other side of the planet, in India, fall at the first hurdle: India was not antipodal to the impact site, 65 million years ago. Furthermore, the fallout layer from the impact is found between the lava flows; in other words, the volcanism was already underway when the impact occurred. So, either there is no direct link between volcanism and impact, or there was more than one impact 65 million years ago. In the case of other extinctions there is scant and sometimes contradictory evidence for an impact at the time of the extinction. We* have argued that there will inevitably be coincidence in time between impacts and flood basalt volcanic activity. But it is also fair to say that we cannot at this stage rule out a sufficiently large impact as a cause for some of these flood basalt provinces.

**White and Saunders, 2005*

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# Earth's own detox programme

**Want to know more?** www.le.ac.uk/gl/ads/SiberianTraps/Index.html