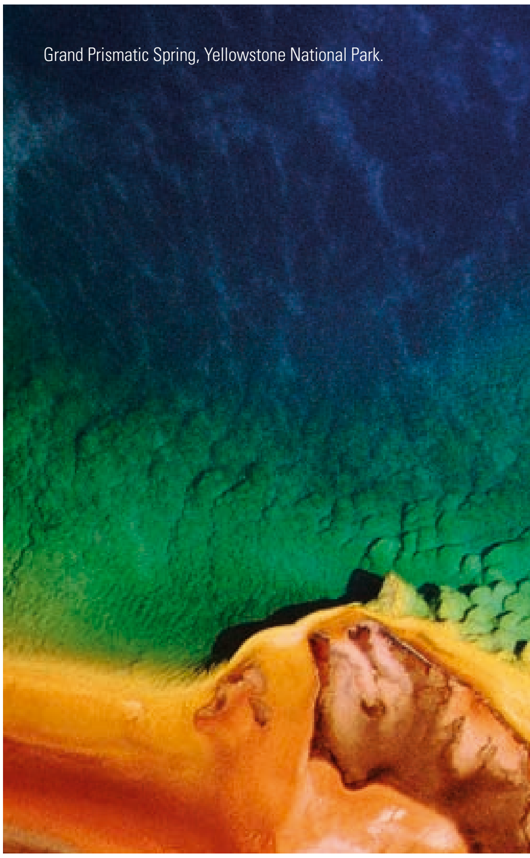
Do volcanoes trigger climate change?



Grand Prismatic Spring, Yellowstone National Park.

Huge volcanic eruptions may have pushed the climate from global warming to global cooling 16 million years ago. The theory could have big implications for efforts to slow climate change by fertilising plankton in the ocean. Sev Kender, Victoria Peck and John Smellie explain.

Some have argued that increasing the productivity of planktonic algae in the world's oceans is a viable means of removing carbon from the atmosphere, counteracting the build-up of industrial CO_2 and mitigating man-made global warming.

When so many planktonic algae flourish that their remains get little chance to decay on the seafloor before they are buried under even more debris, the result is that carbon is removed from the atmosphere for the long term.

Marine sediments dating back 16 million years reveal that in the Middle Miocene period (about 16 to 11.5 million years ago), a trend of global warming was reversed, leading to worldwide cooling. This climatic change went alongside the burial of enormous quantities of organic matter, consisting mostly of planktonic algae, in the Pacific Ocean. While the draw-down of atmospheric CO_2 and global cooling go hand in hand, we don't know what triggered this climatic reversal.

We have studied sediments from the Congo Fan, off the coast of West Africa, an area where very few marine sediment cores have ever been investigated. We found that, as in the Pacific Ocean, substantial quantities of organic carbon were also buried in the Atlantic during the mid Miocene, meaning that increased carbon burial at this time was a truly global event.

At the Congo Fan we find that, like today, stronger winds blowing off Africa forced surface waters away from the shore, and deeper waters welled up in their place. This had a two-fold effect. The upwelled waters would have been rich in nutrients, and dust blown from Africa by the stronger winds would also have fertilised the ocean. The result was that planktonic algae flourished and their bodies were buried in the ocean sediments in vast quantities.

To explain why it became so much windier off West Africa in the middle Miocene we looked at what else was happening in the world at that time.

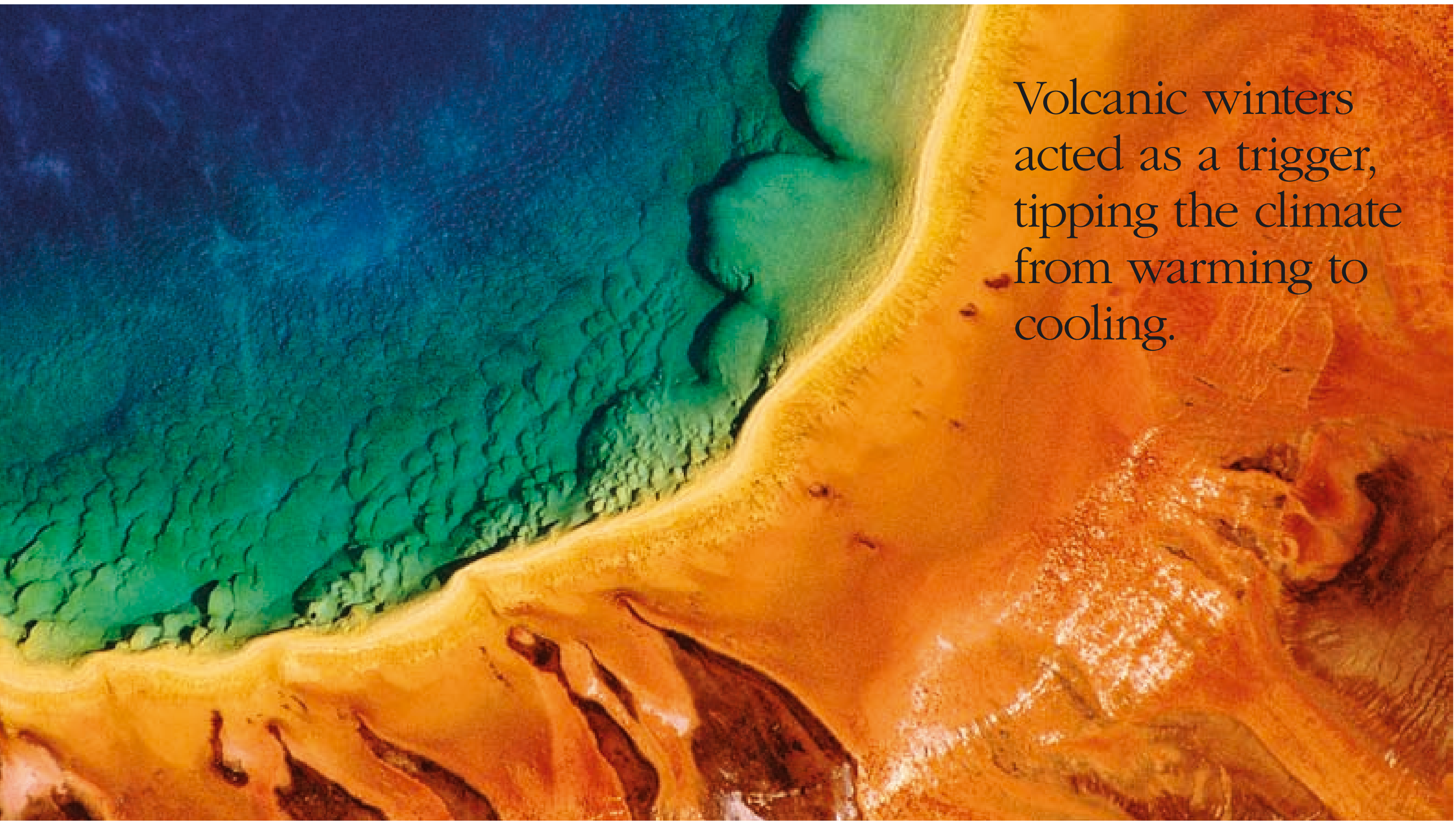
As well as the progressive closure of an equatorial seaway, the Tethys Ocean, we noticed that a huge volcanic eruption of flood basalts in western USA, known as the Columbia River Basalt Group, reached its peak at about the same time as the first increase in burial of organic matter on the Congo Fan. Basalts are very primitive lavas, rich in iron and magnesium, and flood basalt eruptions are the most voluminous eruptions in the world. They release large quantities of CO_2, which could contribute to global warming.

Cooling aerosols

However, they also release great quantities of sulphuric acid, in the form of tiny acidic particles known as aerosols, which can have the opposite effect on climate. The accumulation of sulphuric acid in the atmosphere reflects sunlight before it reaches the Earth and causes the lower atmosphere to cool, counteracting the effect of increasing CO_2 concentrations. Most volcanic eruptions last only days or months, although the cooling effect of sulphuric acid, known as a volcanic winter, may last several years before the acid particles are cycled out of the atmosphere.

But the Columbia River Basalts erupted many times, and each eruption probably lasted decades. This produced vast quantities of sulphuric acid aerosols – amounts not seen on Earth since. The long-term cooling effect on the climate caused by so much sulphuric acid in the atmosphere would have been much more profound than any warming caused by the addition of volcanic CO_2, probably causing global cooling and changing atmospheric circulation patterns. This in turn led to stronger winds over west Africa and caused the planktonic algae to flourish off the coast.

At some point eruption of the Columbia River Basalt Group was complete and sulphuric acid stopped cooling the Earth. But the burial of organic carbon in the oceans continued long after the eruptions had stopped and the climate continued to cool. We therefore concluded that the volcanic winters



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> Volcanic winters acted as a trigger, tipping the climate from warming to cooling.

acted as a trigger only, helping tip the climate from warming to cooling.

Does this trigger exist today, and could it reverse current global warming? Flood basalt eruptions are rare events, and it seems highly unlikely that another flood basalt province will suddenly start erupting. However, although the Columbia River Basalt eruptions are over, the factors causing those eruptions still exist and mean that at some point North America will suffer an even bigger volcano-driven environmental catastrophe, on a scale not experienced in human history.

The Columbia River Basalts were caused by a very hot mass of molten rock, or magma, known as a mantle plume or hotspot, rising in the Earth's deep interior until it collided with the base of the crust. This mantle plume continued to puncture North American crust, causing it to melt and forming a line of large volcanoes, now of a different composition known as rhyolite, that get younger as you move eastwards.

Supervolcanic winter?

These rhyolite magmas differ from the flood basalts because they formed during crustal melting caused by the mantle plume, and are much richer in silica, with far less iron and magnesium. These vast rhyolite structures are known as supervolcanoes, and one of the best known is in Yellowstone National Park.

Supervolcano eruptions might flare up with only weeks, days or even hours of warning, and bring catastrophic environmental devastation. The last full-scale eruption at Yellowstone occurred about 640,000 years ago and ejected a large volume of ash into the atmosphere, covering about half of the United States and probably causing widespread destruction to surrounding ecosystems.

Emissions of SO_2 in some rhyolite eruptions can far exceed those in basalt eruptions, thus potentially triggering a prolonged volcanic winter. Geologists are monitoring the upward movement of the Yellowstone Plateau, as it responds to changes in underlying pressure.

For the past three years the ground has risen three times more rapidly than ever observed since measurements began in 1923. Geologists see no evidence that another such cataclysmic eruption will occur at Yellowstone in the foreseeable future, but recurrence intervals of these events are neither regular nor predictable.

Our results, however, do show that greater global ocean productivity in the Middle Miocene probably led to the removal of atmospheric CO_2 and eventually to global cooling, perhaps lending support to those promoting ocean fertilisation as a viable means to draw down CO_2.

Although we would not discourage attempts to avert the catastrophes associated with human-induced global warming over the coming centuries, the ecological impact of increasing surface water productivity is unknown and may be great. It is worth noting that the Middle Miocene is associated with the largest extinction of deep-sea single-celled organisms (foraminifera) in the past 30 million years.

MORE INFORMATION

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FURTHER READING

S. Kender, V. L. Peck, R. W. Jones and M. A. Kaminski, 2009. Middle Miocene oxygen minimum zone expansion offshore West Africa: evidence for global cooling precursor events. *Geology*, volume 37, issue 8 (August).