Why do some asteroid impacts and mega-eruptions cause mass extinctions while others leave barely a trace in the fossil record? **Michael Reilly** investigates

The Armageddon factor

IT'S a striking feature when seen from above, a circular lake 75 kilometres wide. Manicouagan, also known as the Eye of Quebec, was formed when an asteroid around 5 kilometres across struck northern Canada, gouging out a crater that was originally 100 kilometres wide.

That makes Manicouagan (below right) the fifth largest impact crater on Earth, not much smaller than the 170-kilometre Chicxulub crater in Yucatán, Mexico, site of the impact that ended the reign of the dinosaurs 65 million years ago. Many blame the extinction on a "nuclear winter" caused by the dust and sulphate aerosols thrown up by the impact. Clearly the Manicouagan strike, too, must have had a similar impact.

For a while it was blamed for the mass extinction that marks the end of the Triassic period 200 million years ago. But a 1992 study produced a surprise: it showed the crater is 214 million years old, too old to be the culprit.

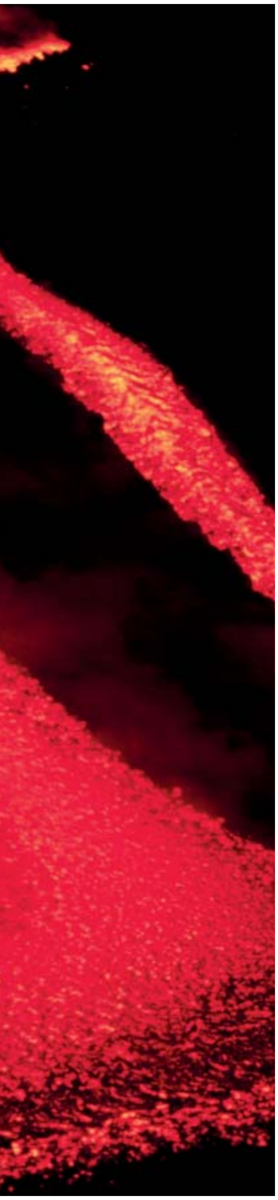
Amazingly, it now looks as if life recovered quickly after the impact, which left hardly a trace in the fossil record. “This was something probably as large as the Chicxulub impact, but there was barely a whimper in terms of climatic or biotic response,” says geologist Michael Arthur of Pennsylvania State University in State College.

Manicouagan is not the only puzzle. About 35 million years ago, a massive asteroid slammed into Siberia, forming the 100-kilometre-wide Popigai crater. This, too, had no apparent long-term effect on life. How is this possible?

The mystery deepens when you consider the immense volcanic events known as flood basalt eruptions. An eruption 250 million years ago covered huge areas of Siberia in basalt up to 6 kilometres thick and has been blamed for the worst ever mass extinction, known as the Great Dying, which marks the end of the Permian period. Global warming triggered by the release of vast amounts of CO_2 from the lava is thought to have played a big role in the extinction.

The Siberian event, however, was dwarfed by a flood basalt eruption that occurred in the western Pacific 120 million years ago. This produced more than 10 times as much lava, covering vast areas of the sea floor in a layer 30 kilometres deep, known as the Ontong Java Plateau. It is the largest known flood basalt eruption and should have released even more CO_2 into the seas and thence the atmosphere than the Siberian lavas, yet resulted in only a minor marine extinction.

So why do some asteroid impacts and flood basalt eruptions devastate life on our planet



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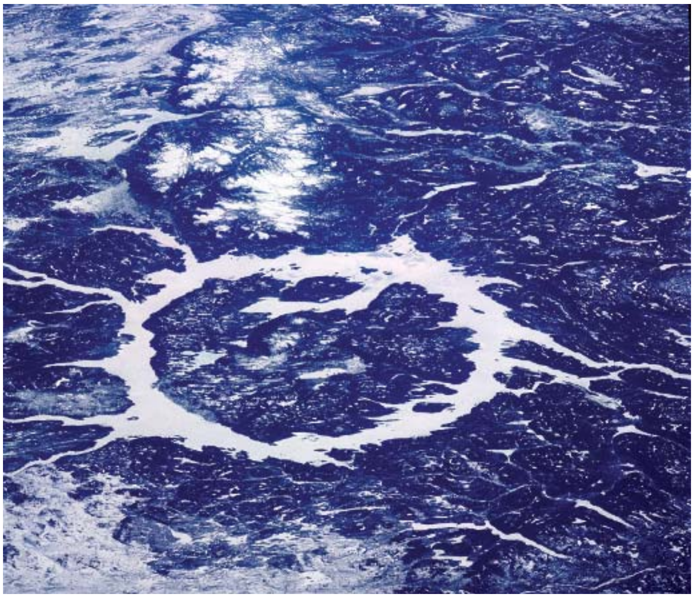

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The Manicouagan impact (above) was nearly as big as the one that killed the dinosaurs, yet had little effect on life

while others make little difference? The answer, some researchers now think, is location: what really matters is what’s in the rocks vaporised by meteorites or roasted by massive eruptions.

Some of the first hints of this came from studies of the Paleocene-Eocene Thermal Maximum (PETM) 55 million years ago, which caused a minor marine extinction. At the time, the Earth was as much as 5 °C warmer than it is today. Temperatures shot up a further 6 to 8 °C in just a few thousand years, with the Arctic Sea surface reaching a balmy 23 °C.

Many deep-sea species vanished, probably because the seas were starved of oxygen. Warmer waters hold less oxygen and can stall ocean circulation, cutting the oxygen supply to the depths – an oceanic anoxic event.

Carbon isotopes show the sudden warming was caused by huge amounts of fossil carbon being released into the atmosphere, but where did it come from? One suspect is the methane hydrate ice buried on the continental shelves, which is very sensitive to changes in temperature. If deep waters warmed rapidly by just 1 or 2 °C, the hydrates could release billions of tonnes of methane – a potent greenhouse gas. Such a “methane burp” could warm the globe.

Then again, what triggered the methane burp in the first place? One idea is that slight warming allowed it to occur spontaneously; another is that an impact is to blame. But the oceans don’t warm for no reason, and no crater of the right age has been found.

Enter Henrik Svensen of the University of Oslo in Norway, whose team was studying the oil and gas-rich Norwegian Sea. The ocean floor there is part of the massive lava fields known as the North Atlantic Igneous Province, formed by the violent opening of the north Atlantic Ocean 55 million years ago. Svensen found that the lava from this huge flood basalt eruption had found its way into carbon-rich mudstone in hundreds of places, insinuating itself between the mudstone layers to form sheets, or sills, between 100 and 300 metres thick. Nearby he found 735 pipe-like hydrothermal vent complexes.

Exploding upwards

Svensen realised that the sills would have heated the mudstones, turning their carbon into methane. This methane would have built up deep below the seabed and eventually exploded upwards, forming the hydrothermal vents. The size and force of the explosions would have sent most of the methane to the sea surface without it dissolving or oxidising to CO_2, as would happen if it was released slowly (*Nature*, vol 429, p 542).

While basalt lava does contain some CO_2, Svensen calculates that the lavas would have baked off at least 10 times as much carbon from the mudstone as if they had simply degassed straight into the atmosphere. This, he thinks, was the trigger for the initial warming, perhaps leading to a massive methane burp later on, which sent temperatures soaring even higher.

The debate over the causes of this event certainly isn’t settled, but more precise dating of rocks supports Svensen’s idea. If he is right, the real cause of the soaring temperatures and the subsequent extinctions during the Paleocene-Eocene Thermal Maximum was the sudden release of large amounts of fossil carbon into the atmosphere. Sound familiar?

Sensing he was on to something, Svensen next went to South Africa to study the 183-million-year-old Karoo-Ferrar large igneous province. This eruption coincided with the ▶