A colossal eruption from the Toba supervolcano rocked early humans. Now a picture of the fallout is emerging from the ashes, says Kate Ravilious.

The first sign that something had gone terribly wrong was a deep rumbling roar. Hours later the choking ash arrived, falling like snow in a relentless storm that raged for over two weeks. Despite being more than 10,000 kilometres from the eruption, hominins living as far away as eastern India would have felt Toba’s fury.

Toba is a supervolcano on the Indonesian island of Sumatra. It has blown its top many times but this eruption, 74,000 years ago, was exceptional. Releasing 15,000 cubic kilometres of magma – nearly twice the volume of mount Everest – the eruption was more than 50,000 times as large as the 1980 eruption of Mount St Helens in the US, making it the largest eruption on Earth in the last 2 million years (see “Bloom now”, page 31).

The disaster is particularly significant since it occurred at a crucial period in human prehistory – when Neanderthals and other hominins roamed much of Asia and Europe, and around the time our direct ancestors, Homo sapiens, were first leaving Africa to ultimately conquer the world. Yet with no recent eruptions for easy comparison, the full extent of its fallout and impact on early humans has been shrouded in mystery.

New dramatic finds from archaeological digs in India, presented in February at a conference at the University of Oxford, are finally clarifying the picture of the eruption and its effects, and how it shaped human evolution and migration. Further results from the digs may even rewrite the timing and route that modern humans took out of Africa.

The new work portrays a somewhat different view of the eruption from the most popular current theory. Previous computer models of the eruption had suggested the event was truly cataclysmic – very nearly a doomsday for early hominins. With calculations based on the assumption that Toba kicked out 100 times more aerosols than the 936 cubic kilometer eruption of mount Pinatubo in the Philippines, and scaling the environmental effects accordingly, the models suggested global temperatures dropped by about 10°C following the blast. This supports the idea of a decade-long “volcanic winter” and widespread catastrophe (Journal of Geophysical Research: Atmospheres, vol 114, p D12205).

To make matters worse, the aerosols would have blocked out life-giving sunlight and absorbed water vapour in the atmosphere, causing a very dry global climate for the next few years. This would have resulted in a rapid decline in tree cover and a concomitant expansion of grasslands, leading to the extinction of many mammals and nearly wiping out our ancestors (Palaeogeography, Palaeoclimatology, Palaeoecology, vol 154, p 295).

The few primitive humans that did survive to eruption would have had to act fast, quickly adapting their way of life to suit the new conditions, travelling further to find food and cooperating with neighbouring populations in the battle for survival. Indeed, the event may have drastically altered the path of evolution for our own species, Homo sapiens. Modern humans, who were still thought to be living in Africa, would have been whittled down to just a few thousand breeding pairs scattered into dispersed refuges – creating a so-called “genetic bottleneck” in evolution. At the separate colonies developed independently of one another, they would have sown the seeds for the genetic differences between races once these separate groups eventually left Africa.

Yet this theory has drawn some criticism since it was first put forward 17 years ago, with scholars such as Hélène Grön, an atmospheric scientist at the University of Cambridge, believing that the climate change following the explosion has been wildly overestimated.

For Grön, the crux of the argument concerns the precise cooling effect of the sulphur dioxide released by the explosion. During smaller eruptions, like that of mount Pinatubo, most of the released sulphur dioxide reacts with water to form sulphuric acid – a highly reflective substance that bounces sunlight back into space before it can warm the Earth. Previous estimates had placed Toba’s sulphur dioxide production at 100 times that of mount Pinatubo’s output. Grön thinks this figure is misguided: recent chemical analyses of Toba’s fossilised magma suggests it should be roughly half that. “We think Toba was more of a giant in ash production, not sulphur,” says Grön.

What’s more, he says, the atmospheric effect of a super-eruption is incomparable to a
"Early humans would have had to adjust to colder temperatures after the eruption, economising as resources dwindled."

This new view is highly contentious. Alan Robock from Rutgers University in New Brunswick, New Jersey, who came up with the original simulations, stands by his original predictions. "Our model showed that extra water would be lofted into the stratosphere because of warming at the top of the troposphere [the lowest layer in the atmosphere], so water would not be a limiting factor," he says. "We simulate a decade or two of very cold, dry, dark conditions, which would have been difficult for humans to adapt to."

Yet recent archaeological and geological work in India seems to support Graf's claims, suggesting the environmental impact of the Toba eruption may have been more significant than previously thought.

"The landscapes after Toba's eruption may give a glimpse of what early humans experienced," says Graf.

"Flight to the refugia"

"We are not saying that it wasn't difficult for humans after Toba," says Milko Petraglia at the University of Oxford, who has led the investigations. "We are just saying that we don't think it was a catastrophic change."

The remains of hominin species living at the time of the eruption would shed some light on life during this difficult period, but sadly no skeletons have been preserved in the sediments. "The most tropical environment is not good for preserving bone," explains Petraglia.

Nevertheless, the tools that they left behind provide a window into their owners' lives. Petraglia and his team have investigated a number of sites at Leakey's, one of which has been particularly fruitful. Labelled Leakey's 22, it was probably a hunter-gatherer camp. It has yielded more than 1200 tools, including stone flakes, scrapers, points — the everyday tools for cutting and scraping — and the stone "cores" left over from the tool manufacture. "The surface is just littered with stone tools, and then buried by the Toba ash," says Michael Haslam, also at the University of Oxford.

Surprisingly, hominins' life appeared to continue in the same vein immediately after the eruption, with hundreds more stone tools in the layers immediately above the ash fall. The team uncovered a similar story 1000 kilometres further north of Leakey's, in the Middle Son river valley. "We see very little change in tool technology across the Toba ashes," says Chris Clarkson, a stone-tool specialist from the University of Queensland in Brisbane, Australia, who worked in the Toba region. Again, that's not to say the eruption was an easy ride for the hominins living in India. Leakey's and the Middle Son valley may have been special cases — refuges in which hominin populations sheltered when the times got tough. Leakey's, for example, is an ancient type of Indian geological formation known as a Deccan basalt, which contains highly fertile soil and abundant freshwater springs protected from contamination by the surface ash. Such circumstances could have buffered some of the effects of the eruption.

"There are springs popping out everywhere in those basins. They contain plentiful rocks for making stone tools and their vegetation is generally resilient to environmental changes," explains Ruth MacIntosh of Kansas State University in Dharwar, India. Still, the findings present a challenge to the traditional view of Toba as a devastating catastrophe for hominins almost the same time as Stanley Ambrose at the University of Illinois at Urbana-Champaign is a leading proponent of the catastrophe theory. He says he has observed strong evidence for technological change in south and east Africa following the eruption, which may have resulted from a need to adapt to pressured conditions, and remnants India should be different. He says that flood erosion may have released some of the tools from the older sediments at the Toba site, re-depositing them in younger sediments and creating the illusion of continuity. Not so, says Haslam. While he admits the artefacts do show some signs of abrasion, he reckons they shifted only a short distance (through the layers of sediment — not enough to skew the dating significantly). Answering such queries is one of the utmost importance, since the new, less-devastating picture of the Toba eruption painted by recent research could have wide ramifications for theories of human evolution and migration. Just how wide depends on which species of human
human produced the tools found in India. According to the traditional view, modern humans did not arrive in this part of Asia until 60,000 years ago or later, at least 14,000 years after the Toba eruption. Before this time, modern humans are thought to have been confined to Africa, barring one failed dispersal to the Levant – the eastern part of the Mediterranean – about 125,000 years ago. If you follow this line of reasoning, the tools thus far must therefore be the product of a more primitive species, perhaps the descendents of Homo erectus, which first occupied India 100,000 years ago or more. The new evidence would still be significant because that is the case, since the survival of these species would suggest that the Toba eruption may not have had a drastic impact on the Homo sapiens populations in Africa either, throwing the "genetic bottleneck" theory of human evolution into doubt.

Petraglia and his colleagues have made many grander claims, however. They report evidence that the tools in India were indeed made by Homo sapiens – a finding that, if true, would rewrite the textbook on human migration from Africa. (" Routes out of Africa.") Previous evidence would just about allow an earlier migration. Fossil evidence from this period of human history is pretty thin in the ground, so scientists have turned to genetics to retread our ancestors footsteps. By analyzing the differences in mitochondrial DNA between modern African populations from different parts of the world, and considering how long it would have taken for these variants to emerge, Martyn Richards at the University of Leeds, UK, Stephen Oppenheimer at the University of Oxford and his colleagues have calculated that the earliest date for a migration out of Africa would have been 75,000 years ago. That is some 50,000 years after Toba blew ( The American Journal of Human Genetics, vol 83, p740). Many other groups go even further, believing the likely date of exit to have been just 60,000 years ago. However, the large uncertainties associated with these techniques give a small probable range for the pre-Toba migration may have been possible.

Indian invasion In fact, there are other reasons to challenge the evidence that has been gathered thus far. Some Australian artefacts suggest modern humans made it to that part of the world no later than 60,000 years ago, and some European and Near Eastern artifacts are from around 60,000 or 70,000 years old. The new evidence, they could argue, was not only more advanced and plant growth across the globe would be disrupted for several years. The Geological Society of London worked as a group one step that 

"In the future, it is likely that the impact of the Toba eruption reveals of super-eruptions may not necessarily be as catastrophic as we once thought. The tools found in India would seem to prove more of the evidence for a pre-Toba migration. Firstly, Clarkson has spotted a subtle change in the way the tools in India were manufactured about 80,000 years ago (50,000 years before the eruption). The tools could be even more similar to those that may be evidence of a Homo sapiens migration at this time. They start to make better use of the stone and strike multiple flakes off in a more radial pattern, often from only one side of the core."

"Clarkson's work is excellent, I'm prepared to argue that Homo sapiens was in India pre-Toba," he says. "If modern humans really did live in India at this time, what route did they take from Africa to Asia? There is some good evidence that modern humans first attempted to leave Africa across treacherous desert regions into the Levant 25,000 years ago. Archaeologists had previously assumed the venture ultimately failed due to the arid conditions, and that it was only much later, when humans tried coastal routes, that they succeeded. Petraglia, however, thinks that the wide range of new evidence in India implies such a route was possible."

"The eruption of St Helens is less catastrophic than that of Toba, but it is the same volcano. We're asking what if that wasn't a failed dispersal?" says Petraglia. "Maybe these people got out across Arabia and went over to India after all."

"There could easily have been a core population of Homo sapiens in southern Arabia by 100,000 years ago," says Griem. "And that population could then have been the source of populations that subsequently dispersed elsewhere across southern Asia."

"In the Indian subcontinent, the Toba eruption caused a lot of devastation, and it seems to support this idea, with remains suggesting that modern humans were adept at crossing desert regions, hopping from oasis to oasis. "In the Toba desert we find fossilised sand dunes. After cutting through these open landscapes we found stone tools inside," says Hermon Atzmon, from Anna University in Chennai, India. Unfortunately, the tools are hard to date precisely, but they do show strong similarities to those found in the Arabian and the Middle East valley."

But here's the killer question: if modern humans did migrate to Asia so early in prehistory, why isn't that (similarly) Journey reflected in modern mitochondrial DNA? Sadie Jones, at the University of Cambridge, UK, thinks that has a solution, but it only makes Toba's importance in human evolution.

She suggests a double dispersal from Africa, with the first waves coming into India pre-Toba around 60,000 years ago and bringing the new tool technology Clarkson observed. Later, when the Toba eruption of 14,000 years ago, a second wave of migrants arrived that sound the death knell for the first "natives." This explains the pre-Toba tools we find in India, but also fits with the genetic data, she says. "If the older population was swept out then no genetic signature would remain."

If this theory reflects the reality, the role of Toba's eruption in human evolution may have been highly significant after all, weakening the first waves of migrants and pushing them into the Indian subcontinent. This explains the pre-Toba tools we find in India, but also fits with the genetic data, she says. "If the older population was swept out then no genetic signature would remain."

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