DID THE TOBA ERUPTION PRODUCED A WIDESPREAD GLACIATION AND A HUMAN POPULATION CRASH?

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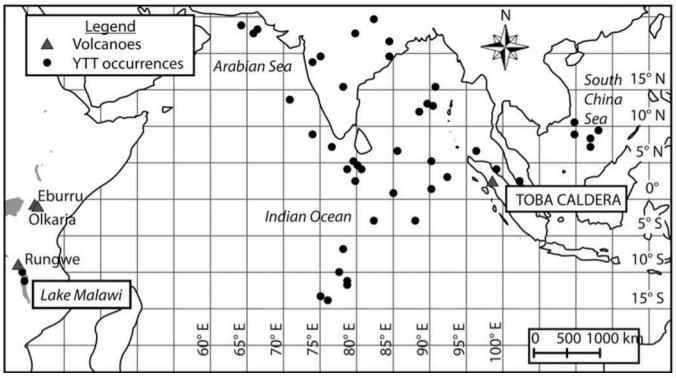
Toba volcano in northern Sumatra is located at the intersection of two major tectonic lineaments in one of the most seismically active regions in the world, and its caldera is considered the largest Quaternary caldera on earth. The most recent Toba explosive eruption at ~74 ka was an order of magnitude larger compared with Tambora in 1815, and has a Volcanic Explosivity Index (VEI) of 8. The exceptional magnitude of this super-eruption and the widespread distribution of the so called Younger Toba Tuff (YTT) in marine cores in the Indian Ocean, the Arabian Sea, the South China Sea and east Africa, have created a sustained debate about its possible global and regional impact on climate, ecosystems and prehistoric human populations.

Toba was no ordinary eruption. It spewed thousands of tons of ash into the atmosphere, enough to probably create a decade-long volcanic winter, leading to massive die-offs of vegetation and the end of some species. That was followed by up to one thousand years of cooler than normal temperatures. The interpreted event was probably so extreme that some scientists have suspected that a volcanic winter resulted from the eruption and it was a big enough to wipe out most early humans, due to some genetic evidence suggesting a reduction of the global human population to just a few thousand survivors, a hypothesis called the **"TOBA CATASTROPHE THEORY".**



The Toba super-volcano has erupted explosively a number of times over the past 1.2 million years. By far the largest and most destructive of these occurred around 74,000 years ago, and the YTT was found between southeast Asia, India and east Africa.

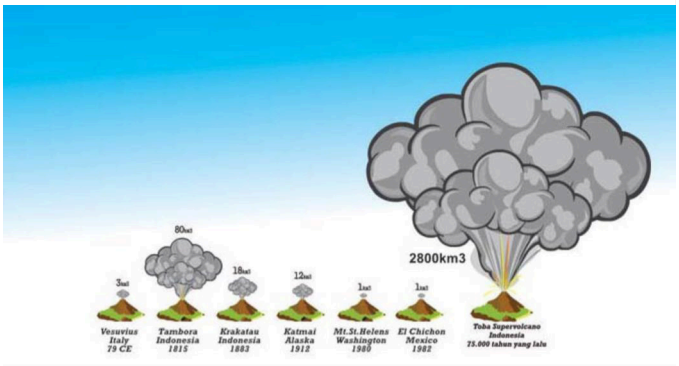
THE TOBA ERUPTION

The largest supervolcano eruption of the past 2.5 million years was a series of explosions of Mount Toba on the Indonesian island of Sumatra about 74,000 years ago. Researchers say Toba spewed out a staggering 2,800 km^3 of magma, equivalent in mass to more than 19 million Empire State Buildings. By comparison, the infamous blast from the volcanic Indonesian island of Krakatoa in 1883, one of the largest eruptions in recorded history, released about 12 km^3 of magma.

A Google Earth image of the caldera on the island of Sumatra. The lake is about 86 km long and 30 km wide, and has a large island inside, the resurgent block of the caldera.

The Toba ignimbrite deposits have been dated by the K/Ar method at 73,500 ± 3,500 B.P., and 40Ar/39Ar age determinations gave 73,000 ± 4,000 B.P. (Chesner et al., 1991). The Toba ash layer occurs also in deep-sea cores from the Indian Ocean at the time of the Oxygen Isotope Stage 5a-4 transition, estimated at 73,910 ± 2,590 B.P. Oppenheimer (2002) reviewed nine different estimates over a wide range, and concluded that the eruption was 74,000 ± 2000 years ago.

The YTT explosion instantly destroyed all life in its sorrounding area, with intensely hot flows of billions of tonnes of ash and rock, accompanied by a deafening noise and powerful tsunamis. It also sent hundreds of cubic kilometers of ash and gases high into the atmosphere, even as the volcano itself collapsed inwards to form a huge sunken caldera (now Lake Toba). The gases, including sulfur, circled the globe on air currents, while the ash spread out to the north and west fanned by prevailing winds. When the ash began to fall, it covered the Indian subcontinent and rained down into oceans from the Arabian Sea in the west to the South China Sea in the east and east Africa (the figure above shows all the locations from which YTT desposits have been recovered to date). Gradually the earth cooled as the sun's heat was reflected by the suspended gases, affecting rainfall and climates across the globe.



The scale of the power of the Toba Super volcano eruption (right) in Indonesia around 74,000 years ago is visualized and compared to other historical well documented volcano eruptions like the Vesuvius volcano eruption of 79 CE and the Krakatau volcano eruption also in Indonesia in 1883 AD.

About the same time the eruption took place, the number of modern humans apparently dropped cataclysmically, as shown by some genetic research (Rampino & Ambrose, 2000). If that so, people today evolved from the few thousand survivors of whatever happen to humans in Africa at the time. The giant plume of ash from Toba, stretched from the South China Sea to the Indian subcontinent and ocean, to the Arabian Sea and eastern Africa, and in the past, investigators proposed the resulting volcanic winter might have caused this human die-off (Rampino & Self, 1993; Rampino & Ambrose, 2000).

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Rampino & Ambrose (2015) showed Evidence from volcanology, ice-core studies, and atmospheric modeling suggesting that the Toba eruption produced a widespread dust cloud, and a dense global H_2SO_4 aerosol cloud that persisted for up to 7.5 yr. The estimated dust and aerosol loadings would have produced regional to global aerosol optical depths between 1 and 10, similar to those predicted in scenarios of nuclear winter. The Toba aerosol cloud was predicted to have caused severe cooling, with immediate temperature decreases to near or below

freezing in the tropics, hard freezes at midlatitudes, and an extended cooling of 3–5° C or more on a global basis. Drought in the tropics from weakening of the Hadley Cell circulation and monsoons is also possible.

Rampino & Ambrose (2015) postulated that the aftermath of the Toba eruption would have constituted a global environmental disaster, with especially severe effects in the tropics, where vegetation lacks cold hardiness. Even in temperate areas, botanical studies predicted that forest and grassland ecosystems could have suffered widespread destruction, with recovery times of about several decades. Furthermore, longer term cooling might have been induced or enhanced by positive feedbacks (e.g., ocean cooling, increased snow cover and sea ice) to the long-lived Toba aerosols. Ice-core evidence from Greenland shows that the Toba eruption coincided with a 200-yr period of sharp cooling that initiated a ca. 1,000-yr stadial event.

Apparently, the Toba super-eruption occurred during a window of time in which the early human population suffered an extreme bottleneck, with some estimates of as few as 3,000 individuals (Rampino & Self, 1993; Rampino & Ambrose, 2000), followed by the expansion of modern humans Botanical studies of the expected damage to natural ecosystems from severe coolings and drought such as expected in the aftermath of Toba predict a global environmental disaster that could have contributed to population crashes of various organisms. The recent discovery of genetic evidence that Eastern Chimpanzees population appear to have undergone a dramatic bottleneck ca. 70,000–60,000 yr ago (Morin et al, 1994), at about the same time of the disaster theory.

NEW EVIDENCE - ASH IN THE MALAWI LAKE (AFRICA)

According to a study by Lane et al (2013), they examined ash from Toba, recovered from mud extracted from two sites at the bottom of Lake Malawi, the second largest lake in the East African Rift Valley. Their analysis discovered that a thin layer of ash in those sediments, about 27 m below the lake floor, was from the last of the Toba eruptions, known as Youngest Toba Tuff (YTT). The Toba super-eruption dispersed huge volumes of ash across much of the Indian Ocean, Indian Peninsula and South China Sea, so the layer of YTT at Lake Malawi was carried about twice the distance as previously thought, over more than 7,000 km.

Lane et al (2013) analyzed the Toba horizon and four additional depths in the same lake, and found the Toba interval recorded a temperature drop of ~1.5 °C relative to sediment above and below this horizon. They stated that the hypothesized "volcanic winter" that followed the Toba eruption did not have a significant impact on the climate of East Africa and was not the cause of a human bottleneck in Africa around 74-75 ka B.P. The authors concluded that The YTT in Lake Malawi was not accompanied by a major change in sediment composition or evidence for substantial temperature change, implying that the eruption did not significantly impact the climate of East Africa and was not the cause of a human genetic bottleneck at that time.

In another study published by Yost et al (2018) in the Journal of Human Evolution, the Toba catastrophe theory was also denied. Those researchers re-examined sediment cores drilled from Lake Malawi in East Africa, where previous studies had identified crystals and glass from the Toba eruption in those cores. Looking at microscopic bits of plant matter preserved in the cores, the same researchers were able to look at vegetation levels 100 years before and 200 years after the eruption. What they found is that there was no cooling or massive die off. It seems the massive explosion did not impact east Africa at all, except for alpine areas.

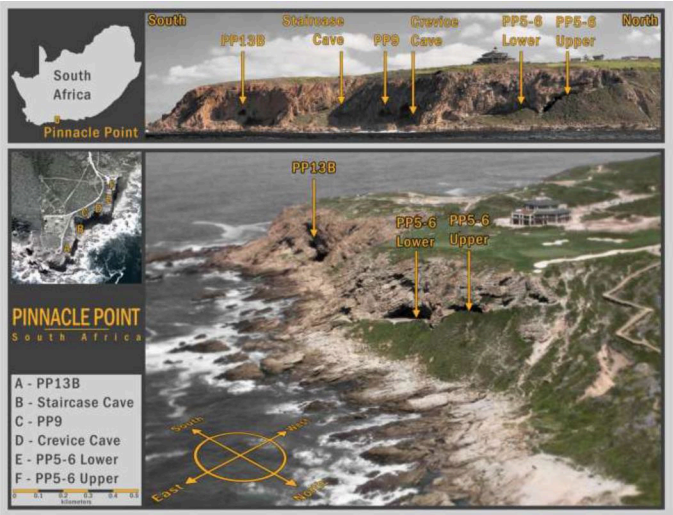
The review of genetic studies by Yost et al (2018) found no support for a genetic bottleneck at or near ~74 ka. Based on previous studies and their paleoenvironmental data, the authors found no support for the Toba catastrophe hypothesis and concluded that the Toba supereruption did not 1) produce a 6-year-long volcanic winter in eastern Africa, 2) caused a genetic bottleneck among African populations, or 3) brought humans to the brink of extinction.

Moreover, paleoclimatic reconstructions by Osipov et al (2021) from the same Lake Malawi sediments and the simulated magnitude of the volcanic winter climate perturbations are the least conflicting among arguments that discredit the Toba catastrophe theory. Climate model simulations do not corroborate the initiation of glaciation, but substantiate the global extent of strong climate cooling. Their global climate simulations with improved representation of stratospheric chemistry and aerosol mechanisms have shown that the volcanic winter effects are significantly less extreme than assumed originally. Their simulations suggested that the global mean cooling could peak at

3.5 °C (rather than 15 °C, assumed previously) and that the sulfate aerosol optical depth (which causes the radiative forcing of climate) returned to background levels within 4–5 years (rather than 20 years).

MORE EVIDENCE FROM AFRICA

Smith et al (2018) at two sites in South Africa (a series of coastal caves inhabited by early humans, called Pinnacle Point and an open-air site called Vleesbaai), sampled the sediments until they found microscopic evidence of the Toba eruption. Using a technique called optically stimulated luminescence, which indicates the last time a grain of sand was exposed to sunlight, those researchers were able to show that the two sites were occupied at the time of the eruption. What Smith et al (2018) found is that Toba did not interrupt the human occupation at the sites, and in fact, during the immediate aftermath of the catastrophe, human occupation intensified The cores indicate that apparently the volcanic winter never took place, or was mild enough not to show up in the sediment record.



The archaeological site in a rockshelter called Pinnacle Point 5-6, on the south coast of South Africa near the town of Mossel Bay. The sediments dated to about 74,000 years ago. Source: Smith et al (2018).

A recent study by Kappelman et al (2024) on an archaeological site in northwest Ethiopia once occupied by early modern humans has added evidence that suggests the Toba event might not have been so apocalyptic as previously published. Microscopic fragments of volcanic glass found alongside stone tools and animal remains in the same layer of sediment at the Shinfa-Metema 1 site, near Ethiopia's Shinfa River, show humans were occupying the site before and after the volcano erupted more than 6,000 km away.

The research found that humans in this location (Shinfa-Metema 1), had the behavioural flexibility required to survive seasonally arid conditions and the apparent short-term effects of the Toba volcanic super-eruption in particular, and that were probably key to the following dispersal and subsequent worldwide expansion of modern humans out of Africa to the rest of the world.

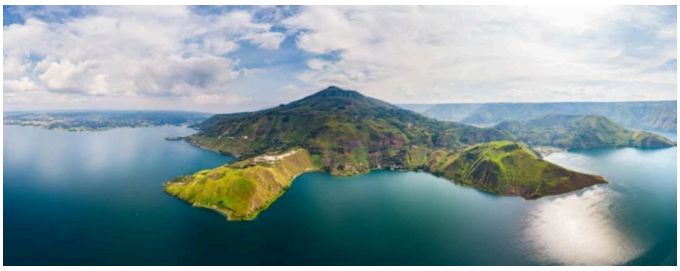
Kappelman and his colleagues have collected thousands of bones, eggshell fragments and arrowheads from the site, called Shinfa-Metema 1, Ethiopia. Source: New York Times.

CONCLUSIONS

The eruption of Toba volcano about 74,000 years ago was one of the largest eruptions of the last few million years and produced at least 2500–3000 km³ of dense rock equivalent pyroclastic ejecta. Of this, over 800 km³ and possibly as much as 2000 km³ constitute the Youngest Toba Tephra or YTT. The YTT covered a huge area of the globe and climate models and Greenland ice core data indicated that the ~74 ka Toba eruption was followed by a few years of intense cold and the global mean cooling could peak at 3.5 °C on a global scale.

Many and more recent genetic and archeological studies found no support for a genetic bottleneck at or near ~74 ka. Based on those studies and new

paleoenvironmental data, none of the most recent research found evidence to support the Toba catastrophe hypothesis and concluded that the Toba super-eruption did not produce a 6-year-long volcanic winter in eastern Africa, or caused a genetic bottleneck among African populations, or brought humans to the brink of extinction.



Actual view of Lake Toba and Samosir Island, Sumatra.

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