

Scientists Revisit an Aegean Eruption Far Worse Than Krakatoa

By WILLIAM J. BROAD

For decades, scholars have debated whether the eruption of the Thera volcano in the Aegean more than 3,000 years ago brought about the mysterious collapse of Minoan civilization at the peak of its glory. The volcanic isle (whose remnants are known as Santorini) lay just 70 miles from Minoan Crete, so it seemed quite reasonable that its fury could have accounted for the fall of that celebrated people. This idea suffered a blow in 1987 when Danish scientists studying cores from the Greenland icecap reported evidence that Thera exploded in 1645 B.C., some 150 years before the usual date. That put so much time between the natural disaster and the Minoan decline that the linkage came to be widely doubted, seeming far-fetched at best.

Now, scientists at Columbia University, the University of Hawaii and other institutions are renewing the proposed connection. New findings, they say, show that Thera's upheaval was far more violent than previously calculated — many times larger than the 1883 Krakatoa eruption, which killed more than 36,000 people. They say the Thera blast's cultural repercussions were equally large, rippling across the eastern Mediterranean for decades, even centuries. "It had to have had a huge impact," said Dr. Floyd W. McCoy, a University of Hawaii geologist who has studied the eruption for decades and recently proposed that it was much more violent than previously thought.

The scientists say Thera's outburst produced deadly waves and dense clouds of volcanic ash over a vast region, crippling ancient cities and fleets, setting off climate changes, ruining crops and sowing wide political unrest. For Minoan Crete, the scientists see direct and indirect consequences. Dr. McCoy discovered that towering waves from the eruption that hit Crete were up to 50 feet high, smashing ports and fleets and severely damaging the maritime economy.

Other scientists found indirect, long-term damage. Ash and global cooling from the volcanic pall caused wide crop failures in the eastern Mediterranean, they said, and the agricultural woes in turn set off political upheavals that undid Minoan friends and trade. "Imagine island states without links to the outside world," Dr. William B. F. Ryan, a geologist at Columbia's Lamont-Doherty Earth Observatory, told a meeting of the American Geophysical Union. Scientists who link Thera to the Minoan decline say the evidence is still emerging and in some cases sketchy. Even so, they say it is already compelling enough to have convinced many archaeologists, geologists and historians that the repercussions probably amounted to a death blow for Minoan Crete.

Rich and sensual, sophisticated and artistic, Minoan culture flourished in the Bronze Age between roughly 3000 and 1400 B.C., the first high civilization of Europe. It developed an early form of writing and used maritime skill to found colonies and a trade empire. The British archaeologist Sir Arthur Evans called the civilization Minoan, after Minos, the legendary king. His unearthed palace was huge and intricate, and had clearly been weakened by many upheavals, including fire and earthquakes. Nearby on the volcanic island of Thera, or Santorini, archaeologists dug up Minoan buildings, artifacts and a whole city, Akrotiri, buried under volcanic ash like Pompeii. Some of its beautifully preserved frescoes depicted Egyptian motifs and animals, suggesting significant contact between the two peoples.

In 1939, Spyridon Marinatos, a Greek archaeologist, proposed that the eruption wrecked Minoan culture on Thera and Crete. He envisioned the damage as done by associated earthquakes and tsunamis. While

geologists found tsunamis credible, they doubted the destructive power of Thera's earthquakes, saying volcanic ones tend to be relatively mild. The debate simmered for decades. In the mid-1960s, scientists dredging up ooze from the bottom of the Mediterranean began to notice a thick layer of ash that they linked to Thera's eruption. They tracked it over thousands of square miles. Dr. McCoy of the University of Hawaii, then at the Woods Hole Oceanographic Institute on Cape Cod, took part in these discoveries, starting a lifelong interest in Thera. By the early 1980s, he was publishing papers on the ash distribution.

Such clues helped geologists estimate the amount of material Thera spewed into the sky and the height of its eruption cloud — main factors in the Volcanic Explosivity Index. Its scale goes from zero to eight and is logarithmic, so each unit represents a tenfold increase in explosive power. Thera was given a V.E.I. of 6.0, on a par with Krakatoa in 1883. The similarity to Krakatoa, which lies between Sumatra and Java, helped experts better envision Thera's wrath. Krakatoa hurled rock and ash more than 20 miles high and its blasts could be heard 3,000 miles away. Its giant waves killed thousands of people.

Despite the power of Thera, the Danish scientists' evidence raised doubts about its links to the Minoan decline. Their date for Thera's explosion, 1645 B.C., based on frozen ash in Greenland, is some 150 years earlier than the usual date. Given that the Minoan fall was usually dated to 1450 B.C., the gap between cause and effect seemed too large. Another blow landed in 1989 when scholars on Crete found, above a Thera ash layer, a house that had been substantially rebuilt in the Minoan style. It suggested at least partial cultural survival. By 1996, experts like Prof. Jeremy B. Rutter, head of classics at Dartmouth, judged the chronological gap too extreme for any linkage. "No direct correlation can be established" between the volcano and the Minoan decline, he concluded.

As doubts rose about this linkage, scientists found more evidence suggesting that Thera's eruption had been unusually violent and disruptive over wide areas. Scientific maps drawn in the 1960s and 1970s showed its ash as falling mostly over nearby waters and Aegean islands. By the 1990s, however, the affected areas had been found to include lands of the eastern Mediterranean from Anatolia to Egypt. Scientists found ash from Thera at the bottom of the Black Sea and Nile delta. Dr. Peter I. Kuniholm, an expert at Cornell on using tree rings to establish dates, found ancient trees in a burial mound in Anatolia, what now is in the Asian part of Turkey. For half a decade those trees had grown three times as fast as normal — apparently because Thera's volcanic pall turned hot, dry summers into seasons that were unusually cool and wet. "We've got an anomaly, the biggest in the past 9,000 years," Dr. Kuniholm said in an interview.

More intrigued than ever, Dr. McCoy of the University of Hawaii two years ago stumbled on more evidence suggesting that Thera's ash fall had been unusually wide and heavy. During a field trip to Anafi, an island some 20 miles east of Thera, he found to his delight that the authorities had just cut fresh roads that exposed layers of Thera ash up to 10 feet thick — a surprising amount that distance from the eruption. Greek colleagues showed him new seabed samples taken off the Greek mainland, suggesting that more ash blew westward than scientists had realized. Factoring in such evidence, Dr. McCoy calculated that Thera had a V.E.I. of 7.0 — what geologists call colossal and exceedingly rare. In the past 10,000 years only one other volcano has exploded with that kind of gargantuan violence: Tambora, in Indonesia, in 1816. It produced an ash cloud in the upper atmosphere that reflected sunlight back into space and produced the year without a summer. The cold led to ruinous harvests, hunger and even famine in the United States, Europe and Russia. "I presented this evidence last summer at a meeting," Dr. McCoy recalled, "and the comment from the other volcanologists was, 'Hey, it was probably larger than Tambora.'"

Dr. Ryan of Columbia has woven such clues into a tantalizing but provisional theory on how distant effects might have slowly undone Crete. First, he noted that winds at low and high altitudes seem to have blown Thera's ash into distinct plumes — one to the southeast, toward Egypt and another heavier one to the northeast, toward Anatolia. Even if the changes wrought by Thera helped trees there, they apparently played havoc with delicate wheat fields. Mursilis, a king of the Hittites, set out from Anatolia on a rampage, traveling between the plumes to strike Syria and Babylon and seize their stored grains and cereals. The subsequent collapse of Babylon into a dark age, Dr. Ryan said, also undid one of its puppets, the Hyksos, foreigners who ruled Egypt and traded with the Minoans. He theorized that the new Egyptian dynasty had no love of Hyksos allies. Therefore, Minoan Crete, already reeling from Thera's fury, suffered new blows to its maritime trade. In an interview, Dr. Ryan said he and other scholars were still refining dates on some of the ancient events, promising to better fix their relation to the eruption. The outcome of that work, he said, could either strengthen or undermine his thesis.

Even without such distant upsets, some prominent archaeologists have concluded that the volcano's long-term repercussions meant the end of Minoan Crete. For instance, they argue that the revolt of nature over the predictable certainties of Minoan religion probably crippled the authority of the priestly ruling class, weakening its hold on society. In scholarly articles, Dr. Jan Driessen, an archaeologist at the Catholic University of Leuven in Belgium, and Dr. Colin F. MacDonald, an archaeologist at the British School in Athens, have argued that changes to Cretan architecture, storage, food production, artistic output and the distribution of riches imply major social dislocations, and perhaps civil war. By 1450 B.C., Mycenaean invaders from mainland Greece seized control of Crete, ending the Minoan era. Thera's destructiveness was probably the catalyst, Dr. Driessen and Dr. MacDonald wrote, "that culminated in Crete being absorbed to a greater or lesser extent into the Mycenaean, and therefore, the Greek world."