

Six medical papyri describe the effects of Santorini's volcanic ash, and provide Egyptian parallels to the so-called biblical plagues

Abstract

An epidemic thought to have been the first instance of bubonic plague in the Mediterranean reveals to have been an episode of tularemia. The deadly epidemic took place in the aftermath of the removal of a wooden box from an isolated Hebrew sanctuary. Death, tumors, and rodents thereafter plagued Philistine country. Unlike earlier explanations proposed, tularemia caused by *Francisella tularensis* exhaustively explains the outbreak. Tularemia fits all the requirements indicated in the biblical text: it is carried by animals, is transmitted to humans, results in the development of ulceroglandular formations, often misdiagnosed for bubonic plague, and is fatal. Moreover, there is the evidence from the box and rodents: mice, which are known carrier for *F. tularensis* and can communicate it to humans, were credited by the very Philistines to be linked to the outbreak, and are small enough to nest in the box. Mice also explain the otherwise odd statement in the biblical text of a small Philistine idol repeatedly falling on the floor at night in the building where the Philistines had stored the box as mice exiting the box would easily have tipped over the statuette. Tularemia scores yet another point: an episode of the disease is known to have originated in Canaan and spread to Egypt around 1715 BC, indicating recurrence for the disease, and suggesting Canaan was a reservoir for *F. tularensis* in the 2nd millennium BC.

An eruption that changed history

The volcanic island of Santorini in the Aegean Sea erupted toward the middle of the Bronze Age with a Volcanic Explosivity Index of 6, i.e., a magnitude similar to the one that halved Krakatoa in 1883. Volcanologists reconstructed the event as follows: at first powerful earthquakes took place for several years; the eruption started when pinkish ash was ejected, a 2-24 month pause ensued, and a final explosion of ash, bombs, lava and other material accompanied by powerful tidal waves, followed [1-4].

The ash is mainly a mixture of two components, highly acidic sulfates and natural glass. The glass was found at the bottom of the eastern Mediterranean, Anatolia [5], as well as at the bottom of the Manzalah Lake adjacent to the Nile Delta, and was dated to the 17th-16th centuries BC [6]. Given the magnitude of the eruption, the copious amounts of ash would have affected humans, cattle, game, harvests, etc. with negative repercussions both on health and the economy. Writing was known in Egypt at the time, so where is the Egyptian documentation on the matter?

The London Medical Papyrus treats burns from acids

Paragraph 55 of the *London Medical Papyrus* (L55), one of 23 treatments for burns (L15-L21 and L46-L61) in the document [7-8], describes a lesion that could not be treated by rinsing because of red waters, but needed a mixture of alkaline materials, and, if left untreated, would generate larvae at a later time. This implies that the burn was due to a caustic agent, derived from the red waters, and its nature was acidic. The formation of larvae means that the exposed skin had offered an hard-to-pass opportunity for insects to place their eggs. The fallout from the initial pink ash from Santorini would have resulted in red acidified waters useless to rinse burns because they themselves were causing the burn [9].

Four additional paragraphs of the *London Medical Papyrus* confirm the presence of patients suffering from volcanic fallout. Thus, burns in the desert caused by means other than the sun rays (*L46-L47*) fit volcanic ash. Two more paragraphs (*L52* and *L56*) mention burns scattered on the body, a feature which would require spraying. In pre-industrial times, the only sprays available would have come from atmospheric dispersion, which is consistent with the fallout [10].

Additionally, *L19* treats blisters alongside burns all over the body. While these burns were scattered like those in *L52* and *L56*, reflecting atmospheric dispersion of the caustic agent, the formation of blisters indicates the agent was present in a different physical form than as a particulate, and was probably diluted in a liquid.

L19 is consistent with volcanic ash, which both falls out and disperses. The latter forms a film that blocks the penetration of solar rays, triggering weather anomalies such as more frequent precipitations [11]. The very first precipitation after the eruption would have dissolved large amounts of the suspended ash, resulting in a very acidic rainfall, explaining the differences between the acidic burns in *L19* and the other paragraphs discussed earlier.

Burns *et al.*

The *L19* prescription also happens to exist as paragraph 549 of the *Ebers Papyrus* (*Eb. 549*), the longest medical text from Ancient Egypt, which was completed by 1550 BC [7-8].

Scanning the 879 remedies of the text, the *Ebers Papyrus* shows that the burn treatment is not an isolated case of treatment of ailments compatible with volcanic ash. In fact, 32% of the document deals with conditions compatible with effects from volcanic ash: skin problems (*Eb. 104-120*), cough and asthma (*Eb. 305-335*), eye problems (*Eb. 336-431*), blisters on the head

(*Eb.* 437-450), burns and lesions (*Eb.* 482-542), issues to the bladder and the gastro-intestinal apparatus (*Eb.* 543-602).

A similar picture emerges in the contemporary *Hearst Medical Papyrus*, which is a general manual, and treats various ailments such as constipation, bones, and bites [7-8]. However, it holds numerous treatments for burns, lungs, nausea, and headaches, all issues coherent with the aftermath of the volcanic ash.

To this list of texts can be added two texts focusing on ophthalmology. The *Carlsberg Papyrus 8* only covers two topics, gynecology and ophthalmology. The latter remedies are almost word for word duplicates of eye remedies in the *Ebers Papyrus* [7-8], thus reflecting the same source. The *Ramesseum Papyrus III*, finalized before 1567 BC, reports 40 remedies. Thereof 15 remedies treat eyes and 4 treat burns [7-8], i.e., close to 48% of the text treated ailments attributable to the effects of volcanic ash. Among these remedies, in spite of the poor state of conservation of the document, it is possible to read details relative to acids affecting the eyes. The remedy numbered *RIII A 17-19* prescribes urine, an alkaline liquid, on eyelids. Moreover, the two remedies numbered *RIII A 19-20*, and *RIII A 25-26*, prescribe *djaret* plant extract for eyelids. Although the identity of the plant is uncertain, its extract is mentioned in the treatment of burns caused by acids in the aforementioned *L46*, *L52*, and *L56* of the *London Medical Papyrus*, singling out an acidic, rather than viral or bacterial, insult to the eyelids.

A medical papyrus testifies to the sociopolitical chaos from the ash

Large natural disasters often result in destabilization of sociopolitical systems. One such instance is known from the military break up of the northeastern Nile Delta in the aftermath of a deadly epidemic around 1715 BC [12]. The effects of the Santorini ash on harvests and other sources of

food would have led to mayhem across the areas affected, which find circumstantial confirmation in a medical document of the time.

The *Edwin Smith Surgical Papyrus* only survived in a truncated form, listing 48 cases of wounds [7-8]. They befit a military surgeon rather than any other surgeon. Even surgical interventions such as the treatment of tumors (except for case 45) deal with wounds rather than cancer: the areas were characterized by redness, pus, and caused fever. Rather than cases of cancer, these tumors are coherent with wounds that got infected, most likely during combat, in full coherence with the rest of the manual.

It is therefore fair to state that this text documents riots and/or a civil war. In other words the ash unleashed the most extreme form of sociopolitical chaos, and contributed to a climate of despair after the destructions operated by the effects of the first and second eruptive phases from the Santorini volcanic event.

Evidence for the biblical plagues of Egypt from the six medical papyri

Medical documents testify to the medical needs of the inhabitants of Egypt towards the end of the Middle Bronze Age, reflecting the effects of Santorini's ash.

The *London Medical Papyrus* and the *Ebers Papyrus* detail two separate species of burns. One is coherent with fallout of acid particles, the best examples in pre-industrial times coming from volcanic ash. The other burn is better explained by precipitation of diluted acids, the best examples in pre-industrial times coming from acid rain that would have dissolved acid particles suspended in the air, and which would have triggered weather anomalies.

The presence of volcanic ash both in particulate and dissolved form is re-echoed in the biblical narrative of the first eight plagues of Egypt (Ex.7.14-12.30) [13]. The fall out would

have dyed the Nile, killing the fish, and turning people away from drinking those waters (Ex.7.14-24) [13]. The ash would also explain the next plague of large numbers of frogs that ended up dying on the river banks (Ex.7.28-8.10) [13]: a Nile contaminated with ash would have pushed the amphibians onto the banks, where they would have died dehydrated, unable to re-enter the water [9]. The flesh of the dead animals and the lesions in the live humans and animals would have attracted insects, resulting in larvae (also mentioned in *L55*), and thereafter adult insects, which is consistent with the third and fourth biblical plagues of crawling invertebrates followed by swarms of various adult insects (Ex.8.12-20) [13].

Moreover, weather anomalies triggered by ash particles forming a film in the atmosphere explain the subsequent four plagues. Herbivores died in the fifth plague (Ex.9.1-7) [13], which fits with grazing animals hit by lightning in a freak storm, and/or eating grass contaminated by sulfates. The chemical would have been readily absorbed by the animals because, unlike ash in particulate form, it would have been dissolved in the rain drops. Humans and animals of the sixth plague covered in boils (Ex.9.8-12) [13] make sense in light of the acid rain to which they would have been exposed. The hail of the seventh plague (Ex.9.13-35) [13] is consistent with these weather anomalies. As for the locusts of the eighth plague (Ex.10.1-19) [13], higher humidity, which is the case since precipitations were more frequent, triggers these insects to multiply [14].

The *Ebers Papyrus*, the *Hearst Medical Papyrus*, the *Carlsberg Papyrus 8*, and the *Ramesseum Papyrus III*, list additional tissues. Of particular interest, given the aforementioned match with the biblical plagues, are the eyes: the ninth plague speaks of a palpable obscurity lasting several days (Ex.10.21-23) [13]. A volcanic plume of gas and ash investing a site and its inhabitants provides the simplest and thus, in light of Ockham's razor, most plausible, explanation in pre-industrial times. This smoke would have obscured the sky and been palpable

because of the ash component. It would have also affected, primarily, the eyes, causing much more serious damage to them than the earlier ash fallout, and acid rain.

Finally, a climate of despair transpires from the massive medical problems, and from the sociopolitical chaos as attested by the *Edwin Smith Surgical Papyrus*. This climate may well be linked to the tenth and last biblical plague of the massacre of the firstborn, and may have also facilitated the escape of the Hebrews as indicated by the biblical narrative (Ex.12.29-39) [13].

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