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Volcanic Eruptions in the Mediterranean Before A.D. 630 From Written and Archaeological Sources

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Written and archaeological sources from the Mediterranean region have been exhaustively searched for evidence of historical volcanism before the year A.D. 630. Volcanic eruptions are identified here by two methods: direct observations, which give information about Mediterranean volcanoes, and indirect, atmospheric observations, which give at least the dates of very large explosive eruptions that occurred somewhere in the northern hemisphere. Seven or more very large explosive eruptions have been detected by these methods. Direct observations indicate great eruptions of Thera (fifteenth century B.C.), Etna (44 B.C.), and Vesuvius (217 B.C., A.D. 79, A.D. 472). Indirect observations imply great eruptions of northern hemisphere volcanoes in the years 217 B.C., 44 B.C., A.D. 472, A.D. 536, and A.D. 626. Some of the correlations with known Mediterranean eruptions may be accidental. It is found that atmospheric veiling and cooling were quite marked for about a year after the eruptions of 44 B.C., A.D. 472, A.D. 536, and A.D. 626 (relevant data are lacking for the other eruptions). If the A.D. 536 eruption was a very distant one (Rabaul, New Britain?), it may have been the most explosive in recorded history. There is independent evidence of the sizes of the eruptions that took place in these years: at least five of them coincide with the strongest acidity signals in Greenland ice for this period. In the case of the smaller eruptions, reliable (though necessarily incomplete) chronologies are presented for Etna, Vesuvius, and the other active Mediterranean volcanoes. Full documentation from the original sources is provided throughout.

INTRODUCTION

The establishment of an accurate record of historic volcanism has long been recognized as important not only for analysis of volcanic eruption frequencies but also for the study of global climate change. Explosive eruptions are often able to inject large quantities of aerosols into the upper atmosphere, producing an apparent dimness of the sun and other unusual optical effects for periods ranging from months to years, over wide areas of the earth [*Symons*, 1888; *Lamb*, 1970; *Deirmendjian*, 1973; *Pollack et al.*, 1976]. Reports of these atmospheric aftereffects are in many cases the only evidence of major eruptions which were not observed directly or which were reported with insufficient detail to ascertain their explosive magnitude [*Lamb*, 1970].

Eruptions that produce such atmospheric phenomena are of considerable interest as possible perturbers of the earth's climate. Volcanic ash and volcanogenic sulfuric acid aerosols in the stratosphere absorb and backscatter some of the incoming solar radiation and hence are theoretically able to cool the earth's surface [*Pollack et al.*, 1976; *Hansen et al.*, 1978]. Studies of surface temperatures after large historic eruptions have identified a significant short-term (up to 3 years) hemispheric cooling of a few tenths of a degree Celsius [*Mass and Schneider*, 1977; *Taylor et al.*, 1980; *Self et al.*, 1981]. Longer-term cooling after large eruptions is also theoretically possible through positive feedback mechanisms like increased snow and ice cover [e.g., *Bray*, 1976].

Reports of other volcanically produced atmospheric phenomena such as widespread haze or "dry fog," unusual twilights, and associated optical effects that have been observed over the past several hundred years have been collected in several works (F. A. R. Russell in the work by *Symons* [1888]; *Heilprin* [1908]; and *Lamb* [1970]). Few such instances, however, have been reported for earlier historical times. One source of very early accounts is the literature of ancient Mediterranean civilizations. We have searched this literature in order to assemble a complete catalog of all very large volcanic eruptions reported from the Mediterranean region for the pre-A.D. 630 historical period. The cutoff date of A.D. 630 marks approximately the beginning of the Arabic era.

In the course of our research, we found that previously published catalogs of European volcanic eruptions contain many errors and omissions for the ancient period. A major part of our work, therefore, has been to replace the previous catalogs with a new one through a complete and critical reading of the original literature. To this end, we have investigated not only the major eruptions having demonstrable widespread significance but also the smaller eruptions, which had only local effects. Finally, we have been able to make inferences about the overall state of volcanic activity in the Mediterranean during the ancient historical period.

PRECEDENTS AND PRELIMINARIES

Among the large number of previous catalogs of ancient Mediterranean volcanism, we have examined most carefully those compiled by the following authors: Catanti in the work by *Mecatti* [1752]; *della Torre* [1755]; *Capaccio* [1771]; *Recupero* [1815]; *Alessi* [1829, 1830]; *von Hoff* [1840]; *Daubeny* [1848]; *von Humboldt* [1850]; Scacchi in the work by *Roth* [1857]; *Phillips* [1869]; Bunbury and others in the work by *Smith* [1870]; *Lyell* [1875]; *Judd* [1875]; *Palmieri* [1880]; *Sartorius von Waltershausen* [1880]; *Nissen* [1883]; *Johnston-Lavis* [1884]; *Huelsen* [1894]; *Sapper* [1917, 1927]; *Chevallier* [1924]; *Alfano and Friedlaender* [1929]; *Radke* [1958]; *Georgalas* [1962]; *Imbo* [1965]; *Hirschboeck* [1980, unpublished catalog, 1976]; and *Simkin et al.* [1981]. None is an exhaustive or even completely independent catalog, and errors have multiplied with time. In each of the last three catalogs, for example, we find that for Mediterranean erup-

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tions within the period 1500 B.C. to A.D. 630, erroneous or omitted dates are more numerous than correctly cited dates by about 50%.

Our new search of the ancient literature (the equivalent of about a quarter of a million pages of modern English text) enables us to assess the real nature and completeness of the ancient volcanic record. Like others, we find that Biblical and Egyptian literature is generally too sparse and too ambiguous concerning natural phenomena to be really useful and is applicable mostly to the period before ca. 700 B.C. The Greek and Roman classical literature with which we are primarily concerned is fairly abundant but very heterogeneous in subject matter, quality, and coverage in time. For the medieval period up to A.D. 630, we have examined the Latin, Byzantine Greek, Syriac, and Armenian literature (the last two sources in translation), but the records are again quite sparse. Archaeological data, mostly bearing on the fifteenth century B.C. eruption of Thera and the A.D. 79 eruption of Mount Vesuvius, are useful to some extent. In spite of the limitations of the data at our disposal, most ancient reports of volcanic eruptions are not suspiciously linked to important contemporary historical events or restricted to the portent literature, and therefore they may be considered quite reliable. A detailed discussion of how much reliability can be placed in each ancient author and his sources, and of how dates are assigned to ancient authors and to the events they describe, is beyond the scope of this article; but a good reference for this kind of information is the *Oxford Classical Dictionary*.

It is clear that a complete record of ancient volcanism cannot be put together from the surviving fragments of ancient texts. Nevertheless, in the case of the most explosive eruptions, having the kind of widespread and obvious atmospheric effects mentioned earlier, the record is probably very nearly complete for the time period ca. 700 B.C. to A.D. 630, at least in Europe. For somewhat smaller eruptions, we estimate the following time intervals within which near completeness of the eruption record can be assumed: for Etna, 696–425 B.C. (from Thucydides' explicit testimony) as well as at least 141–32 B.C. (from the detailed annual lists of Italian prodigies, or unusual natural phenomena, provided by Julius Obsequens, Cassius Dio, and Appian); for Vesuvius, ca. 200 B.C. to A.D. 79 (from Dio's explicit testimony); and for Thera, at least 199 B.C. to A.D. 77 (from Pliny the Elder's explicit testimony). For other times, other volcanoes, and smaller eruptions we are at the mercy of the accidents of manuscript survivals. It must always be kept in mind as well that the Greeks did not colonize Italy until ca. 750 B.C. (Sicily ca. 735 B.C.), that is, the time of Homer, and that the earliest extant Greek history was not written until ca. 430 B.C. Likewise, detailed Roman records for the period before the sack of Rome by the Gauls in ca. 390 B.C. were generally unavailable to the first Roman historians, who were writing ca. 200 B.C. Prior to these critical dates, Greek and Roman history must be regarded as largely legendary.

A word about our citation of historical references is necessary. Ancient authors and their works are cited here directly in the text. Titles, however, are provided only where necessary to eliminate ambiguity or obscurity. Chronological order of authors cited together (or of their sources if known) is strictly followed; dates are normally explicitly provided in most cases. English translations of the texts are either our own or else adaptions from standard versions, where these follow closely the original texts.

The following abbreviations are used: *CIL*, *Corpus Inscriptionum Latinarum*; *MGH*, *Monumenta Germaniae Historiae Auctores Antiquissimi*; *PG*, Migne's *Patrologia Graeca*; *PL*, Migne's *Patrologia Latina*; Bollandists, Bollandist Fathers' *Acta Sanctorum*.

Major Explosive Eruptions

Etna: 44 B.C.

Surviving literature from the Augustan age (27 B.C. to A.D. 14) and slightly earlier relates that after the assassination of Julius Caesar on March 15, 44 B.C. there was a dimming of the sun that cannot be attributed today to a solar eclipse (Mark Antony in Josephus, *Jewish Antiquities* 14.309; Vergil, *Georgics* 1.463–468; Tibullus 2.5.75–76; Ovid, *Metamorphoses* 15.785–790; Manilius 2.595). Although Mark Antony and Vergil were actually living in 44 B.C., it is not entirely certain that their vague allusions refer to anything other than the darkness of a violent thunderstorm that followed immediately after Caesar's murder (Dio, *Roman History* 44.52.1; see also the similar allusions made by the fourth century authors Servius, *Commentary on Vergil's Georgics* 1.466, and pseudo-Aurelius Victor, *On Famous Men* 78). However, Tibullus, who was a much younger poet of the Augustan age, records more specifically a phenomenon that can be dated to the same year from internal evidence within his poem:

> Light departed from the Sun himself, and the cloudy year saw him yoke dim horses to his chariot.

Fortunately, there exist better historical authorities from later ages, who attest to this phenomenon even more explicitly. Their ultimate source was most likely Livy (born ca. 59 B.C.), who covered this period in the now lost Books 116 and 117 of his Roman history. One of these authorities, Pliny the Elder (A.D. 77) (*Natural History* 2.98), informs us

> Portentous and protracted eclipses of the sun occur, such as the one after the murder of Caesar the dictator and during the Antonine war which caused almost a whole year's continuous gloom.

Similar reports can be found in Dio (third century A.D.) (45.17.5) and in Obsequens (fourth century A.D.?) (*Book of Prodigies* 68). However, the fullest account is provided by Plutarch (ca. A.D. 100) (*Caesar* 69.3–4):

> Among events of divine ordering there was . . . after Caesar's murder . . . the obscuration of the sun's rays. For during all that year its orb rose pale and without radiance, while the heat that came down from it was slight and ineffectual, so that the air in its circulation was dark and heavy owing to the feebleness of the warmth that penetrated it, and the fruits, imperfect and half ripe, withered away and shrivelled up on account of the coldness of the atmosphere.

This account is very similar to the classic description by Benjamin Franklin of the "dry fog" that persisted over Europe at the time of the 1783 eruption of the volcano Laki in Iceland [*Lamb*, 1970, p. 433]. Such a dimming of the sun (and moon) has been reported by naked-eye observers after many large volcanic eruptions and has been consistently noticed and reported after explosive eruptions more than have any other unusual optical phenomena. Reports of "dry

fogs" in Europe usually follow relatively local eruptions (southern Europe, Iceland, Canary Islands, etc; see *Lamb* [1970, Appendix I]), although the great Tambora (Indonesia) event in 1815 was followed by reports of dry fog in Europe and eastern North America [*Post*, 1977]. This suggests that the eruption that produced the phenomena of 44 B.C. in Italy might have been a European eruption.

Plutarch's mention of a crop failure in 44 B.C. probably explains Tibullus' (2.5.84–86) reference to a renewed abundance of grain and grapes after the gloomy year 44. However this may be, Cicero, writing in early June of 44, notes that such important men as Brutus and Cassius were urgently appointed grain commissioners by the senate (Cicero, *Letters to Atticus* 15.9–12; see also the second century author Appian, *Civil Wars* 3.6, 3.35, 4.57). Later, on September 2, he refers to a famine that is "in part present and in part impending" (*Philippics* 1.6.13). Clearly, more may be implied by Cicero's remarks than just the economic and political consequences of the civil war. The following year an oracle predicted that grain would not be harvested in the coming summer (Obsequens 69). The fact that this prediction was recorded suggests that it may have come true. On the other hand, a letter from Asinius Pollio to Cicero (in Cicero, *Letters to his Friends* 10.33) proves that grain was plentiful at least around Cordova, Spain, in June of 43. All we can safely conclude is that the crops failed in 44 and may have failed also in 43, at least in some parts of the Roman world.

Several workers [*Lamb*, 1970; *Post*, 1977; *Stommel and Stommel*, 1979] have proposed that disastrous crop failures in Britain and northeastern North America following cold and rainy summers may have been related to explosive volcanic eruptions, for example, Tambora (Indonesia) in 1815 and the series of eruptions in various parts of the world in the 1690's. *Lamb* [1970] has noted further that the three coldest summers in the northeastern United States between 1780 and 1960 were years of considerable volcanic dust veils.

The hazy condition of the atmosphere described by Plutarch had other reported effects. Although no contemporary account exists, Obsequens (68) reports the tradition:

> When at the third hour of the day [about 9 a.m.] he entered Rome, surrounded by a huge crowd, the sun, enclosed within a small circle of clear and calm sky, surrounded Octavius with the end of an arc such as the rainbow usually displays in the clouds . . . . [At another time] three suns shone, and around the lowest sun a wreath like the wreath of heads of grain flashed into view surrounding it.

With generally less detail, other authors have described both the remarkable solar halo (Velleius Paterculus 2.59.6; Seneca, *Natural Questions* 1.2.1; Pliny the Elder 2.98; Suetonius, *Augustus* 95; Dio 45.4.4; Orosius, *Against the Pagans* 6.20; John Lydus, *On Portents* 10b) and the pair of mock suns (Pliny the Elder 2.99; Dio 45.17.5; Eusebius-Jerome, *Chronicle*, Olymp. 184). Appian (*Civil Wars* 4.4) mentions "fearful signs" around the sun in the following year 43, and three authors refer to a display of mock suns again in 42 (Pliny the Elder 2.99; Dio 47.40.2; Obsequens 70).

The unusual atmospheric phenomena of 44–42 B.C. are similar to those that are known to follow large explosive volcanic eruptions which inject aerosols into the stratosphere. Increases in the aerosol optical depth of the stratosphere give rise to a decrease in the direct solar beam [*Humphreys*, 1940; *Lamb*, 1970; *Hoyt*, 1979], and scattering by dust particles and sulfuric acid drops leads to optical phenomena such as a blue or green color to the sun or moon, unusual twilights, mock suns, and Bishop's rings (a colored aureole-corona complex within a circular region around the sun or moon, with a visual radius of 20°–30°) [*Symons*, 1888; *Heilprin*, 1908; *Deirmendjian*, 1973]. Such unusual optical phenomenon have been reported after many great volcanic eruptions, for example, Krakatau in 1883, the 1902–1903 series of eruptions (including Santa Maria and Pelée), Katmai in 1912, and Agung in 1963.

As for the cause of the unusual atmospheric conditions in 44–42 B.C., volcanic aerosols from an eruption of Mount Etna in 44 B.C. are one possibility. Vergil (*Georgics* 1.466–473) relates

> After the death of Caesar . . . how often we saw Etna flooding out from her burst furnaces, boiling over the Cyclopean fields, and whirling forth balls of flame and molten stones.

Servius (*Commentary on Vergil's Georgics* 1.472) says in explanation of this passage

> As Livy relates, before Caesar's death such flame flowed down from Mt. Etna that not only the neighboring cities but even the city of Regium were blasted by it.

Livy's more authoritative date, being set in an annalistic history, is to be preferred to Vergil's, although the word quotiens ("how often") in Vergil may imply a continuing series of eruptions. Probably, the primary eruption occurred early in 44. Its destructive range was at least 70 km, since apparently a hot ash fall crossed the Straits of Messina and struck what is now known as Reggio di Calabria. Appian (*Civil Wars* 5.114) confirms that lava flowed into the sea, which is 18 km from the summit, and earthquakes were reported as far away as Rome (Vergil, *Georgics* 1.479; Ovid, *Metamorphoses* 15.798; Dio 45.17.4; Obsequens 68). In the *Aeneid* (3.571–582), Vergil supplies further details of the eruption:

> Etna thunders with terrifying crashes, and now hurls forth to the sky a black cloud, smoking with pitch-black eddy and glowing ashes, and uplifts balls of flame and licks the stars—now violently vomits forth rocks, the mountain's uptorn entrails, and whirls molten stones skyward with a roar, and boils up from its lowest depths . . . . Mighty Etna . . . from its burst furnaces breathes forth flame; and . . . all Sicily moans and trembles, veiling the sky in smoke.

Some authors, both ancient and modern, have suggested that this vivid description is a mere reworking of Pindar's description (probably eyewitness) of an eruption in ca. 475 B.C. (*Pythian Odes* 1.19–28). However, its originality is confirmed by the similarity of its language to that in the cited passage of *Georgics*, together with Servius' commentary, as well as by the significant differences of content from Pindar's poem, which were pointed out originally by the critic Favorinus in the second century A.D. (Aulus Gellius 17.10; Macrobius, *Saturnalia* 5.17). Finally, we have the testimony of Pliny the Elder (2.234), undoubtedly referring to the same eruption:

> Etna . . . is so hot that it belches out sands in a ball of flame over a space of 50 to 100 [Roman] miles at a time.

The range mentioned for the "ball of flame" (probably a hot ash fall) corresponds to about 75–150 km, which considerably exceeds the volcano's normal range of about 30 km, also given by Pliny (3.88).

Modern field studies of Etna have uncovered a stratigraphic record of major past explosive activity [*Keller et al.*, 1978; *Guest and Duncan*, 1981] that ended during the early Middle Ages [*Kieffer*, 1979]. The few available radiocarbon dates in the period of interest (890 B.C., A.D. 110, 140, and 190, all with mean errors of about ±100 years) cannot be definitely reconciled with the dates of any known historical eruptions. The lack of an accurate empirical dating method renders mostly conjecture, in our opinion, the many attempts [e.g., *Romano and Sturiale*, 1981] to correlate the undetailed (but well dated) ancient eruption reports with specific volcanological features in the case of such a continuously active volcano as Etna. Nonetheless, lava flows are reported in ancient times to have traveled east to the sea, west to the Simeto River, and south to Catania (*Aetna* 487, 508; Table 1), distances which agree well with modern observations [*Imbo*, 1965]. A fairly large recent eruption of Etna that bears some resemblance to the 44 B.C. event occurred in 1886. The eruption column was estimated to be 14 km in height, while haze and mist following this eruption blocked out the sun in Sicily; within 2 weeks the haze had spread throughout Italy [*Lamb*, 1970].

Further evidence of a great 44 B.C. eruption comes from a time record of acidity in a Greenland ice core analyzed by *Hammer et al.* [1980]. A strong 3-year acidity peak was dated by them at about 50 ± 30 B.C. and has been confirmed at ca. 40 B.C. in another ice core by *Herron* [1982]. Hammer et al. suggested that it is due to one of the largest volcanic eruptions in the northern hemisphere since the last glaciation. They proposed that if the heavy sulfuric acid fallout in Greenland were to be ascribed to Etna, the magnitude of the eruption and its impact on Roman society would have been so great that there would undoubtedly be geological and historical evidence. We believe that the historical evidence assembled in this paper supports the occurrence of a major explosive Etnan eruption in 44 B.C. Etna's known sulfur richness [*Wadge and Guest*, 1981] also suggests that a very large eruption of this volcano could have produced the observed acidity peak in Greenland ice.

Of course, we realize that the acidity signal in the Greenland ice as well as the atmospheric effects of the time may have been the result of one or more remote and as yet unknown eruptions. Alternatively, a known but distant eruption that might be relevant is the very large Sunda (Indonesia) eruption, which on archaeological grounds is estimated to have occurred at about the time of Christ [*van Bemmelen*, 1971]. Another possibility is the Alaskan White River (north lobe) eruption which has been radiocarbon dated at about A.D. 60 ± 100 [*Lerbekmo et al.*, 1975].

Vesuvius: 217 B.C., A.D. 79, and A.D. 472

We present next the literary evidence for another major volcanic eruption, one that occurred in 217 B.C. In that year the Roman pontiffs apparently recorded a dry fog, as "the sun's disk seemed to be diminished" (Livy 22.1.9).

It was also noted in 217 B.C. that a shower of "glowing stones," suddenly appearing from the south (Silius Italicus 8.650-651), had fallen at the town of Praeneste, near Rome (Livy 22.1.9; Plutarch, *Fabius Maximus* 2.3), while at Capua, 30 km north of Naples, there had been "the appearance of a sky on fire" (Livy 22.1.12). Round glows in the sky and a sudden darkening of the sun seem also to have been observed from the east coast of Italy near Mount Gargano (Livy 22.1.9; Silius Italicus 8.632-633). A record number of violent earthquakes, too, had been felt throughout Italy in that year (Coelius Antipater in Cicero, *On Divination* 1.78; Livy 22.5.8; Pliny the Elder 2.200; Silius Italicus 5.611–633, 8.627–649; Plutarch, *Fabius Maximus* 3.2; Florus, *Epitome* 1.22.14). But most significantly of all, Mount Vesuvius is said by the first century A.D. epic poet Silius Italicus (*Punica* 8.653–655) to have erupted:

> Vesuvius also thundered, hurling flames worthy of Etna from her cliffs; and the fiery crest, throwing rocks up to the clouds, reached to the trembling stars.

Although Silius included this information in a long list of prodigies for the year 216, some of these prodigies appear also in Livy's (22.1.8–13) list for the year 217, which should be preferred as the correct date. The simile with Mount Etna is of course derived from Vergil and at first sight makes this prodigy suspect. But a later passage (Silius Italicus 12.152–154) details the aspect of the Campanian mountain in 215 B.C.:

> Hannibal is shown Mt. Vesuvius, where fire has eaten away the rocks at its summit, and the wreckage of the mountain lies all around, and the discharge of stones seeks to rival the death dealt by Etna.

This passage is conspicuously free of the mythological associations that Silius attaches in his poem to other volcanoes.

In the Augustan age, Diodorus Siculus, Vitruvius, and Strabo, while recognizing Vesuvius's volcanic character, thought that the mountain had been extinct since prehistoric times. But Strabo (1.2.18, 5.4.8) does inform us that the summit in his day was barren and ash-colored, and Diodorus Siculus (4.21.5) and Vitruvius (2.6.2-3) agree that the mountain still displayed in their day the signs of earlier fire. These facts suggest that the last eruption had occurred in the not too distant past, which would support Silius' testimony. There is also the more general argument that according to modern critics, Silius' historical and geographical facts, whenever they can be checked, usually hold up [*Nicol*, 1936]. Furthermore, the independently reported distant effects of the eruption closely resemble the ones observed after the more famous eruption of A.D. 79.

Discussion of the more important A.D. 79 eruption, which buried Pompeii, Herculaneum, and other towns under thick layers of ash, pumice, and lahars, must be based principally on the two detailed accounts given by Pliny the Younger (*Letters* 6.16, 6.20). Although Pliny's accounts are too long to be quoted here, many geological texts present them in full [e.g., *Bullard*, 1976]. Countless authors have attempted to reconstruct in detail the sequence of events occurring during the eruption; for example, strong evidence for the development of two nuées ardentes has recently been found by *Sigurdsson et al.* [1982]. Our principal contribution here will be to provide a complete guide to the numerous other ancient authorities, to draw attention to the uncertainty of the key dates, to determine the approximate configuration of the volcano just before the eruption, and to discuss the eruption's wider physical consequences.

It seems to be almost universally believed that prior to its massive outburst, Mount Vesuvius had the form of a single truncated cone. When the top of the volcano collapsed or

blew off, it left only the steep ridge of the present Mount Somma to the north and east. This belief rests primarily on two descriptions given by Strabo and Dio, supplemented by a Pompeian wall painting.

"The summit of Mt. Vesuvius is in large part flat," observed Strabo (5.4.8) in the first century B.C. Dio (66.21.1), writing in the third century A.D., stated that "once Mt. Vesuvius was equally high at all points." And the Pompeian wall painting [*Kusch*, 1960, Plate 2] does show a single (though not truncated) peak. But consider the context of this evidence as well as some further information. Strabo has also mentioned "hollows and valleys" and evidence of "craters of fire in earlier times" at the summit, while Dio appears to be making only a reasoned conjecture about the prehistoric condition of the mountain. Dio's additional remarks about the outlying peaks (Mount Somma) retaining their original height and supporting abundant vines are very similar to the descriptions of that part of Mount Vesuvius occupied by Spartacus and his troops in 73 B.C., although these descriptions have admittedly come down only in post-A.D. 79 authors (Frontinus, *Stratagems* 1.5.21; Plutarch, *Crassus* 9.1–2; Florus, *Epitome* 2.8.4). The Pompeian wall painting mentioned above depicts Vesuvius in a very peculiar montage with explicitly mythological subjects. Therefore a number of more relevant wall paintings showing more realistic landscapes should certainly also be considered. Two of them, one from Pompeii [*Trevelyan*, 1976, Plate 59] and the other from Herculaneum [*Kusch*, 1960, plate on p. 5], show different views of Vesuvius as seen from the neighborhood of Naples, but two mountain peaks. Two other wall paintings from Pompeii [*Spinazzola*, 1953, Plates 859 and 861] display almost identical views of Vesuvius as seen from Herculaneum, but three peaks (the peak farthest to the left in one of these wall paintings, which seems to be an abridged copy of the other, is almost entirely cut off). Modern photographs confirm that the Somma-Vesuvius massif appears dominantly single, double, and triple, as seen from Pompeii, Naples, and Herculaneum, respectively [e.g., *Trevelyan*, 1976, Plates 3 and 4; *Kusch*, 1960, Plate 3]. Although the height of the main cone of Vesuvius has varied considerably over the centuries, the basic profile of the mountain just before the A.D. 79 eruption seems not to have been radically different from its present shape.

Although the year of the A.D. 79 eruption is well established (Dio 66.17–26; Eusebius-Jerome, Olymp. 214; Zonaras, *Annals* 11.18), the month and day are not (Pliny the Younger, *Letters* 6.16). The two-day event probably occurred during August 24–25, but later dates (perhaps as late as November 1–2) can be argued from the variant text readings [e.g., *Doering*, 1843]. The eruption is known to have been closely observed from Misenum by Pliny the Younger, who afterward made detailed inquiries about it from other witnesses. Two or three decades later, he wrote for the historian Tacitus a detailed description of the whole event (including the death of his uncle Pliny the Elder) as seen from different points around the Bay of Naples (Pliny the Younger, *Letters* 6.16, 6.20). The eruption may well also have been observed by the poet Statius (*Silvae* 2.6.61–62, 3.5.72–73, 4.4.78–86, 4.8.5, 5.3.205–208) and possibly by Silius Italicus, who often resided in Campania. In addition to the devastating local effects of this eruption, we are told by later historians that the sun was darkened at Rome for many days and that ash fell there and in even more distant places like Tripolitan Africa, Egypt, and Syria (Dio 66.23; Procopius, *Wars* 6.4.27; Zonaras 11.18) and perhaps farther in the east (Silius Italicus 17.592–596). The notoriety of this eruption in antiquity is attested by the numerous references or allusions to it made by other persons who were living at the time (Josephus, *Jewish Antiquities* 20.144; Valerius Flaccus 3.208–209, 4.507–509; Tacitus, *Histories* 1.2, *Annals* 4.67; Martial, *Epigrams* 4.44; Plutarch, *On the Pythian Responses* 398E, *On the Late Vengeance of the Deity* 566E; Suetonius, *Titus* 8, *On Famous Men*, *s.v.* Pliny; *Sibylline Oracles* 4.130–136) and by many later authors as well (Marcus Aurelius 4.48; Tertullian, *To the Nations* 1.9, *Apology* 40, *On Penitence* 12, *On the Pallium* 2; Dio 66.21–24; Eusebius-Jerome, Olymp. 214, 221; *Epitome of Caesars* 10; Orosius 7.9). Marcus Aurelius (ca. A.D. 175) is the earliest known author to mention the destroyed cities by name and to refer to them as "dead" cities.

It is noteworthy that the eruption was not only accompanied but also preceded by many local earthquakes (Pliny the Younger, *Letters* 6.16, 6.20; Dio 66.22), especially one or two very violent ones at dates that are uncertain but must lie between A.D. 62 and 64 (Seneca, *Natural Questions* 6; Tacitus, *Annals* 15.22, 15.34; Suetonius, *Nero* 20; *CIL*, *10*(1), 846, 1406). This eruption and the one of 217 B.C. seem to have been associated in a similar way with numerous ground shocks.

Another major eruption of Vesuvius occurred in the year A.D. 472, according to Count Marcellinus (*Chronology*, Mommsen, *MGH*, *11*, 90), a reliable writer of the sixth century,

> Vesuvius, a burning mountain of Campania, seething with internal fires, vomited up its completely consumed inner parts and turned day into night, covering the whole surface of Europe with a fine dust. Every year on November 6, the people of Constantinople celebrate the memory of these terrifying ashes.

Although there is no extant contemporary account of this prodigious event, other authors of the sixth century also mention various aspects of it (Procopius, *Wars* 6.4.27; John Lydus, *On Portents* 6; Victor Tonnennensis, *Chronology*, Mommsen, *MGH*, *11*, 195; Theodorus Lector, *Ecclesiastical History*, Migne, *PG*, *86*(1), 177; John Malalas, *Chronography*, Migne, *PG*, *97*, 553). According to Theodorus Lector, "fiery clouds" had been observed in the sky before the ash fell. John Malalas gives the final depth of ash on the roofs of Constantinople as "one palm's breadth" (a standard unit, normally equal to ~8 cm). George Cedrenus (eleventh century) (*Histories*, Migne, *PG*, *121*, 668) adds the information that the ash fall began around noontime. Many other Byzantine chroniclers record both the fiery clouds and the depth of the ash. Somewhat different years, however, are noted for the date. John Lydus gives "the time of Zeno" (A.D. 474–491); an anonymous seventh century chronicler (*Easter Chronicle*, Migne, *PG*, *92*,, 828), A.D. 469; Theodorus Lector and George Cedrenus, A.D. 473; Theophanes Confessor (tenth century) (*Chronography*, Migne, *PG*, *108*, 300), A.D. 474; and Victor Tonnennensis, A.D. 513. A passage from Count Marcellinus (p. 97, Mommsen), however, corrects the date given by Victor Tonnennensis. (These dates are all referred to A.D. 474 as the year of the emperor Leo I's death.) Late Near Eastern chroniclers wrongly give the date (if it refers to the same ash fall) as A.D. 429/430 (*Edessan Chronicle* 57; *Chronicle to A.D. 846*, p. 210,

Chabot; Michael the Syrian, *Chronicle* 8.176, Chabot). Finally we have a contemporary report from Portugal for one of the years during the emperor Anthemius' reign (A.D. 467–472) (Hydatius, *Chronicle*, Mommsen, *MGH, 11*, 35):

> At this same time, there was a year of exceptional harshness, extending through winter, spring, summer, and autumn, when a great change took place in the atmosphere and in all the fruits.

The 8-cm thickness of ash reported to have fallen on Constantinople (1200 km east of Vesuvius) is quite extraordinary if attributed to the Italian volcano. By comparison, the huge explosive eruption of Tambora in 1815 put less than 2.5 cm of ash at Batavia, about 1300 km from the volcano [*Petroeschevsky*, 1949]. The depth of ash reported from Constantinople may refer only to a palm's thickness of ash, or perhaps to wind-driven drifts, or, possibly, to an unrelated ash fall which accompanied a great fire in Constantinople that occurred at about the same period (for evidence of the chronological confusion, see John Malalas, col. 553, Migne; *Easter Chronicle*, cols. 821, 829, Migne; Leo the Grammarian, *Chronography*, p. 114, Bekker).

Modern studies of pumice fall deposits that are widely dispersed over the areas to the northeast, east, southeast, and south of Mount Vesuvius have uncovered evidence for at least eight large plinian eruptions [*Lirer et al.*, 1973; *Delibrias et al.*, 1979; *Rosi et al.*, 1980]. The sequence and chronology of these eruptions, however, must be somewhat incomplete because of the poor exposure and frequent lack of superposition of the deposits, the paucity of datable material, and the similarity of the pumice deposits of different eruptions. Only three pumice layers have been studied in any detail. The Pollena pumice, dispersed east-northeast and radiocarbon dated to about A.D. 360 ± 60, may have originated in the A.D. 472 eruption. The Pompeii pumice, with an axis of dispersal toward the southeast, has been correlated with the A.D. 79 eruption. An older deposit, the Avellino pumice, dispersed toward the northeast, has been radiocarbon dated to the second millenium B.C.

If the 217 B.C. eruption of Vesuvius was a large plinian event, there should be corresponding pumice fall deposits widely dispersed in surrounding areas. The regional geologic studies now available have not detected the predicted layer of pumice. Perhaps further sampling in the areas to the east or northeast of Vesuvius (the inferred direction of dispersal of the 217 B.C. ash) is required. However, an explosive event need not have ejected a large amount of pumice. Archaeological studies suggest that Pompeii, to the southeast, escaped essentially unscathed. But it is tempting to speculate that the large change in Pompeian art style at ca. 200 B.C. [*Van Buren*, 1952] may have been related to possible earthquake damage to the city in 217 B.C. A similar change in art style definitely occurred after the earthquakes of A.D. 62–64.

More recent eruptions of Vesuvius, though of lesser magnitude, have also produced wide-ranging atmospheric effects analogous to those of the ancient eruptions [*Lamb*, 1970; *Symons*, 1888]. For example, after the 1717 eruption, there was an ash-produced darkness 160 km from the volcano. The 1813 and 1822 eruptions were followed by dimming of the sun in northern Italy, whereas the 1831 eruption of Vesuvius preceded an extraordinary dry fog that persisted throughout Europe and North Africa and was reported as far away as Siberia and the United States. The haze in the latter case may have been only partly due to Vesuvius; large eruptions in the Mediterranean Sea (Giulia) and the Philippines (Babuyan) were also reported in 1831. The most recent explosive eruption of Vesuvius in 1944 caused darkness at Bari, 200 km from the volcano.

Unknown Volcanoes: A.D. 536 and A.D. 626

Four historians who were living in the year A.D. 536 have left surviving accounts of that extraordinary year. Procopius (*Wars* 4.14.5) writes

> And it came about during this year that a most dread portent took place. For the sun gave forth its light without brightness, like the moon, during this whole year, and it seemed exceedingly like the sun in eclipse, for the beams it shed were not clear nor such as it is accustomed to shed.

John Lydus (*On Portents* 9c) confirms the account:

> The sun became dim . . . for nearly the whole year . . . so that the fruits were killed at an unseasonable time.

In the Syriac chronicle associated with the name of Zacharias of Mytilene, we read (*Chronicle* 9.19, 10.1, Hamilton and Brooks)

> The earth [at Constantinople] with all that is upon it quaked; and the sun began to be darkened by day and the moon by night, while the ocean was tumultuous with spray (?) from the 24th of March in this year till the 24th of June in the following year . . . . And, as the winter [in Mesopotamia] was a severe one, so much so that from the large and unwonted quantity of snow the birds perished . . . , there was distress . . . among men . . . from the evil things.

The severity of the winter of 536/537 in Mesopotamia is independently attested by another contemporary writer, John of Ephesus (*Ecclesiastical History*, pp. 297–298, Land). A very late chronicler, Michael the Syrian (twelfth century), whose source was probably John of Ephesus, provides a little further information (*Chronicle* 9.296, Chabot):

> There was a sign in the sun the like of which had never been seen and reported before . . . . The sun became dark and its darkness lasted for eighteen months. Each day it shone for about four hours, and still this light was only a feeble shadow. Everyone declared that the sun would never recover its full light. The fruits did not ripen and the wine tasted like sour grapes.

No significant additional information about this event is provided by other late chroniclers who mention it. It should be noted that the Byzantine annalists give the duration of dimming of the sun as close to one year, whereas the chroniclers slightly farther south mention 18 months. This suggests a volcanic aerosol cloud that may have slowly spread northward.

Whether a European volcanic eruption provided a source of aerosols that obscured the sun in A.D. 536–537 cannot be determined with any certainty. Procopius, who was present in Campania early in 536, says (*Wars* 6.4.21-28)

> At that time the mountain of Vesuvius rumbled, and though it did not break forth in eruption, still because of the rumbling it led people to expect with great certainty that there would be an eruption . . . . When the mountain gives forth a rumbling sound which resembles bellowing, it generally sends up not long

> afterward a great quantity of ashes .... Formerly this rumbling took place, they say, once in a hundred years or even more, but in later times it has happened much more frequently.

The prior eruptions of Vesuvius that are specifically known to us from ancient reports occurred in (or in about) the years 217 B.C., A.D. 79, A.D. 202, A.D. 472, A.D. 505, and A.D. 512. Perhaps shortly after Procopius moved north to Rome from the neighborhood of Vesuvius, the mountain did erupt. But in that case it is strange that Procopius would not have eventually heard about the eruption or experienced an ash fall at Rome and mentioned it in his history (see also *Wars* 8.35.1–6).

The last ancient record of dimming of the sun, in A.D. 626, is found in Michael the Syrian (*Chronicle* 11.409, Chabot):

> In the year A.D. 626 the light of half the sphere of the sun disappeared, and there was darkness from October to June. As a result people said that the sphere of the sun would never be restored to its original state.

The meaning seems to be that the intensity of the sun, with or without an apparent change of diameter, diminished by about one half (see also Bar-Hebraeus, *Chronography* 10.96, Budge). George the Monk (tenth century) (*Chronology*, Migne, *PG*, *110*, 828), referring to the year A.D. 626 (or possibly A.D. 618), says that "the sun became dim; moreover, ashes rained down." The context of an identical passage by Michael Glycas (fifteenth century) (*Annals*, Migne, *PG*, *158*, 516) indicates that the ash fall was reported at Constantinople. Could it have been due to an eruption of Vesuvius or of some other Mediterranean volcano? A very late Irish chronicle, *Annals of Ulster*, mentions that the year A.D. 624 (wrongly for A.D. 626?) was "dark." The only possible contemporary notice is a Byzantine allusion to an unusual "darkness" at some time not long before the year A.D. 628 (George of Pisidia, *Heraclias* 1.81). According to several of the Near Eastern chroniclers, unusually cold winters occurred around this time, although none can be assigned specifically to A.D. 626/627.

Hammer et al. [1980] have reported an acidity signal in Greenland ice at A.D. 623 ± 3, which is in good agreement with our historical date for the dry fog. They have also noted that in a new ice core from Greenland, another strong acidity signal can be preliminarily dated at A.D. 540 ± 10, which *Herron* [1982] confirms (giving ca. A.D. 535). Hammer et al. have suggested that this latter signal may be a result of the large Alaskan White River (east lobe) eruption, radiocarbon dated at about A.D. 700 ± 100 [*Lerbekmo et al.*, 1975]. We believe, however, that the White River eruption is more likely to be represented in Greenland ice by the acidity peak measured at A.D. 757 ± 3. From our historical evidence for an intense Mediterranean dry fog in A.D. 536, we suggest that the eruption detected by Hammer et al. and Herron may have occurred in that year. It was probably a distant eruption; Rabaul, New Britain, radiocarbon dated at about A.D. 540 ± 90, is a possible candidate [*Heming*, 1974]. If so, it could have been the greatest aerosol-producing eruption in recorded history.

Thera: Fifteenth Century B.C.

A large volcanic eruption of Thera (Santorini) in the Aegean Sea occurred in the fifteenth century B.C. Its possible role in the destruction of Minoan civilization on Crete was first suggested on geologic grounds by *Marinatos* [1939], while, as early as 1909, *Frost* [1939] argued that Plato's lost island of Atlantis was the Crete of Minoan times. Further literary, archaeological, and geological investigation has amplified and solidified these ideas [e.g., *Ninkovich and Heezen*, 1965; *Galanopoulos and Bacon*, 1969; *Luce*, 1969]. Recently, *Hammer et al.* [1980] have detected in a Greenland ice core a very strong acidity peak around the year 1390 ± 50 B.C., which they have related specifically to the great Thera eruption.

OTHER ERUPTIONS

To supplement our preceding discussion of the greatest known eruptions occurring in, or reported from, the ancient Mediterranean, about which there is (as we have seen) a rather surprising amount of available information, we present a catalog of all the known ancient Mediterranean eruptions (Table 1). Too few details are known about the smaller eruptions to warrant extensive discussion, but we do supply a full set of references to them. Estimates of the eruption intensities are also provided, using the following abbreviations: VL, very large; L, large; M, medium; S, small. Uncertainties in the assigned years of these eruptions are indicated by a hyphenated range for the date or simply by ca. (Note that the hyphenated range for the years does not indicate continuing activity.) Some discrepancies exist with the years assigned in previous catalogs; one should not inadvertently infer from this that different eruptions occurred in these years.

To complement the catalog of specific eruptions, we will give below a brief summary of more general evidence concerning ancient volcanic activity in the Mediterranean. We emphasize that the surviving records are so far from complete that there is no point in listing the many miscellaneous reports of minor phenomena like solfatara fields, fumaroles, hot springs, crater lake phenomena, etc.

Chronology is often a problem. The dates of several ancient authors (or of their sources) are poorly known, and, if no specific eruption is mentioned, it is sometimes unclear whether an author is referring to activity in his own time or in some earlier time. Nevertheless, we are in a position to rule out many of the claimed "eruptions" listed in earlier catalogs. In what follows, we shall identify explicitly the most frequently mentioned of these spurious eruptions, giving the original source of error in each case. One exception will be the unpublished catalog of K. K. Hirschboeck (1976), in which the number of newly committed errors for the ancient period is so large as to render this part of the catalog of little use.

Aeolian Islands

Eighth century B.C. Smoke and fire appeared in the Aeolian Islands (Homer, *Odyssey* 10.1–3, 12.59–72, 12.202, 12.219; cf. scholia to 10.1, 10.20; Diodorus Siculus 5.7.7; Strabo 1.2.9, 6.2.10; Eustathius, *Commentary on Homer's Odyssey* 10.1, 10.21, 12.70). It can be assumed that Homer is transferring his contemporary geographical knowledge to these accounts of the mythical (but, traditionally, thirteenth century B.C.) voyages of Odysseus and of the Argonauts (for the latter voyage, see also Apollodorus, *Library* 1.9.25, *Epitome* 7.20).

Late sixth century B.C. Lipari (Vulcano?) active after a 16-year quiescence (Xenophanes in pseudo-Aristotle, *On Marvellous Things Heard* 38).

Late fifth century B.C. Vulcano active (Thucydides 3.88).

But no specific eruption ought to be inferred from *Simkin et al.* [1981]

Late fourth century B.C. Fire in the Aeolian Islands and in the neighboring sea (Theophrastus in Antigonus of Carystus, *Marvels* 145; Theophrastus in scholium to Apollonius Rhodius, *Argonautica* 4.834; pseudo-Aristotle, *On the Cosmos* 395b20-23, *On Marvellous Things Heard* 37, 105).

Early third century B.C. Vulcano active (Callias in scholium to Apollonius Rhodius, *Argonautica* 3.41; Theocritus, *Idylls* 2.133-134). No specific eruption, though, ought to be inferred from *Simkin et al.* [1981]. Callias mentions two craters, one of which had a circumference of 3 stadia (600 m); the second one probably formed during the eruption of ca. 330 B.C. (see Table 1). Much later, in 215 B.C., the sea was reported to be on fire (around the Aeolian Islands?) (Livy 23.31.15; Zonaras 9.3).

Mid second century B.C. Vulcano active (Polybius in Strabo 6.2.10). Polybius reported three craters; the third was probably formed during the eruption of 183 B.C. (see Table 1). The largest crater apparently had a circumference of 5 stadia (900 m) and a height above sea level of 1 stadium (185 m).

First century B.C. Fire appeared on the islands of Vulcano and Stromboli and in the neighboring sea (pseudo-Scymnus, *Periegesis* 254–261; Diodorus Siculus 5.7.1–7; Strabo 5.4.9, 6.2.10–11; Varro in Servius, *Commentary on Vergil's Aeneid* 1.52; Vergil, *Aeneid* 8.416–422). Stromboli's activity is first explicitly mentioned in this century. The sudden birth of an islet near Vulcano, dated by some modern authors at 91–87 B.C. (following Pliny the Elder 2.238), probably occurred in 126 B.C. (see Table 1). On the other hand, a rain of ashes was reported to have fallen at Athens in 88 B.C. (Pausanias 9.6.6). Another supposed eruption of Vulcano, in ca. 44 B.C., was listed by *Kircher* [1678] as a result of his confusing the eruption of Etna in 44 B.C. with the nearly simultaneous eruptions of Etna and Vulcano in 126 B.C.

First century A.D. Vulcano and Stromboli active (Justin-Trogus 4.1; Ovid, *Metamorphoses* 14.86–87; Pomponius Mela 2.7; *Aetna* 435–448; Pliny the Elder 3.93–94; Silius Italicus 14.56–57). For a brief period, though, Vulcano was quiet.

Mid second century A.D. Vulcano and Stromboli active (Pausanias 10.11.4). *De Dolomieu* [1783] described an eruption of Vulcano in A.D. 144 in terms that are almost identical to those he applied to the well-known eruption in A.D. 1444. We suggest that the unspecified author who was his source made an obvious error in transcribing the date.

A.D. 200–250. Vulcano and Stromboli active (Philostratus, *Picture Gallery* 2.17; Solinus 6).

A.D. 250–500. No information is available for this period. *Alfano and Friedlaender* [1929] have wrongly inferred an eruption of Stromboli somewhere in the period A.D. 379–395 from Pacianus, who mentions only Etna and Vesuvius (see below).

Sixth century A.D. Vulcano and Stromboli active (Cassiodorus, *Variae* 3.47; Stephanus of Byzantium, *s.v.* Strongyle; Gregory the Great, *Dialogues* 4.30).

Alban Mount

First millenium B.C. Nissen [1883] has described an early Alban necropolis covered by a mudflow of presumably volcanic origin.

Circa 640 B.C. Rain of stones at the Alban Mount—legendary (Livy 1.31.1–4, 7.28.7; Pompeius Festus, *s.v.* Novendiales; scholium to Juvenal 4.60). The date certainly cannot be as late as 540 B.C., as listed by *Sapper* [1917]. In any case, statistical evidence from Livy and Obsequens suggests that "rains of stones" were reported from central Italian territory about once every three years, on the average, before the Roman Imperial period; these "stones" cannot be volcanic in origin in most cases (they are probably large hailstones).

257 B.C. Rain of stones at the Alban Mount (Zonaras 8.12).

212 B.C. Rain of stones at the Alban Mount (Livy 25.7.7).

113 B.C. Alban Mount seemed to be on fire at night (Obsequens 38). Could this have been a forest fire? Probably the Alban volcano became extinct before 640 B.C.

Arabian Volcanoes

Ancient historical sources make no definite mention of volcanic eruptions in Arabia, although a number of Biblical passages could have been inspired by eruptions in that region before 700 B.C. [e.g., *van Padang*, 1963]. Van Padang has also noted some possible lava flows in early medieval times that are perhaps alluded to by Arab authors writing after A.D. 630.

Argaeus (= Erciyas Dagi)

In the late first century B.C., fire emerged around the base of Mount Argaeus in Cappadocia (central Turkey) (Strabo 12.2.7). Dying volcanism is sometimes thought to be the most obvious explanation since the mountain is volcanic [*Frazer*, 1914; *Wood*, 1982], but Strabo's detailed description may rather refer to burning marsh gas. Claudian (*Against Rufinus* 2.30–31, *Against Eutropius* 2.114–115) is occasionally cited on this question, but his two references seem to be only metaphors describing the effects of war. Cappadocian coins of the Roman Imperial age sometimes show Mount Argaeus surmounted by one or three stars. These stars are not representations of volcanic eruptions but rather are symbols of the local deity (Solinus 46) and perhaps also of Mithra and of the sun god [*Sydenham*, 1933].

Chimaera (= Yanar)

Fourth century B.C. Fire emerged from a chasm atop Mount Chimaera in Lycia (southern Turkey) (Ctesias in Antigonus of Carystus, *Marvels* 182; Ctesias in Pliny the Elder 2.236; Ctesias in Photius, *Library* 72; pseudo-Scylax, *Periplus* 100; Palaephatus 28; pseudo-Aristotle, *On Marvellous Things Heard* 127).

A.D. 1–70. Fire burned on Mount Chimaera and on the nearby mountains of Hephaestium (Ovid, *Metamorphoses* 9.647; Seneca, *Letters* 79; Pliny the Elder 2.236, 5.100). Pomponius Mela (1.15), however, refers to "former fires."

Third century to fourth century A.D. Fire emerged from a chasm atop Mount Chimaera (Solinus 40; Methodius in Photius, *Library* 234; scholium to Homer, *Iliad* 15.189; Servius, *Commentary on Vergil's Aeneid* 6.288; Diodorus of Tarsus in Photius, *Library* 223). According to Methodius and Jerome (*Letters* 54), the mountain was also called Olympus. It has been identified as being near Adrasan Burnu in a nonvolcanic region (T. A. B. Spratt in work by *Smith* [1870]). Its small, unquenchable flame apparently arose from burning naphtha.

Eifel Field

In A.D. 58, flames shot up from the ground somewhere near Cologne (Tacitus, *Annals* 13.57). *Furneaux* [1891] interpreted this as the burning of a peat moor by spontaneous combustion. However, the Eifel region, just south of Cologne, is known to have been volcanic in prehistoric times.

Etna

Fifteenth century to eleventh century B.C. Mount Etna had violent eruptions—legendary (Diodorus Siculus 5.6.3). The uncertain date of these pre-Greek eruptions hinges on when the Sicels invaded Sicily, but it is probably closer to the eleventh century B.C. than to an earlier century (see Thucydides 6.2; Dionysius of Halicarnassus, *Roman Antiquities* 1.22). A late myth relates that the Argonauts (traditionally of the thirteenth century B.C.) saw Mount Etna in eruption (pseudo-Orpheus, *Argonautica* 1250). Myths of earlier times, for example, the stories of Typhon, Enceladus, Hephaestus, and the Cyclopes [*Huelsen*, 1894], suggest very early Greek knowledge of Etna's activity.

Eighth century B.C. Mount Etna active (Hesiod, *Theogony* 860; cf. Eratosthenes in Strabo 1.2.14; Tzetzes' scholium to Lycophron, *Alexandra* 688–689). But a specific date of 735 B.C. cannot be inferred (contrary to *Imbo* [1965]). Hesiod is probably describing the scanty geographical knowledge of his own time. Curiously, Homer does not mention Mount Etna.

Circa 430 B.C. Empedocles fell or threw himself into the fires of Mount Etna according to an ancient tradition (Strabo 6.2.8, 6.2.10; Horace, *Poetic Art* 464–466; Tatian, *Address to the Greeks* 3; Lucian, *Dialogues of the Dead* 416, *The Dead Come to Life* 2, *The Runaways* 2, *Icaromenippus* 13, *The Passing of Peregrinus* 1, 4; Tertullian, *Apology* 50, *On the Soul* 32; Diogenes Laertius 8.69–75; Lactantius, *Divine Institutes* 3.18; Gregory of Nazianzus, *Epigrams* 28, *Poem to Nemesius* 281–284, *Epitaphs* 69; Claudian, *Panegyric on the Consulship of Manlius* 72; Sozomen, *Ecclesiastical History* 2.24; Hermias, *Derision of the Pagan Philosophers* 8; *Greek Anthology* 7.123, 7.124, 8.28; *Suda*, *s.vv.* Amyclae, Empedocles). No actual eruption is implied, and a date of 565 B.C. [*Imbo*, 1965] is incorrect.

Circa 387 B.C. Plato seems to have witnessed a lava flow of Mount Etna (Plato, *Phaedo* 111E; Apuleius, *On Plato* 1.4; Athenaeus 11.507; Diogenes Laertius 3.18; Sozomen, *Ecclesiastical History* 2.24; Olympiodorus, *Life of Plato*).

Late fourth century B.C. Etna active (Theophrastus in Diogenes Laertius 5.49; pseudo-Aristotle, *On the Cosmos* 395b20–23, *On Marvellous Things Heard* 38, 40, 105).

First century B.C. Etna active (Posidonius in Strabo 6.2.3; Lucretius 1.722–725, 6.680–702; Diodorus Siculus 4.21.5, 5.7.3–4; Strabo 5.4.9, 6.2.8–10). According to Strabo, the circumference of the summit crater was 20 stadia (3700 m). Specific eruption dates of 61, 56, and 10 B.C. given by *Imbo* [1965] cannot be supported from the ancient reports.

First century A.D. Etna active at times (Justin-Trogus 4.1; Ovid, *Metamorphoses* 15.340–355; Pomponius Mela 2.7; Seneca, *Letters* 51, 79; *Aetna*, *passim*; *Aetna* in Servius, *Commentary on Vergil's Aeneid* 3.571; Pliny the Elder 2.236, 3.88; Valerius Flaccus 2.30–32; Silius Italicus 14.58–69; Apollodorus, *Library* 1.6.3; Philostratus, *Life of Apollonius* 5.14–17; Philostratus in Photius, *Library* 241; Longinus, *On the Sublime* 35.4). Around the middle of the century, Etna was apparently relatively quiet (Seneca, *Letters* 79). *Sartorius von Waltershausen* [1880], however, has greatly exaggerated a stock description of Mount Etna provided by Pomponius Mela in order to suggest an eruption in ca. A.D. 50. He and Bunbury [*Smith*, 1870] have also suggested another eruption in A.D. 70–72, purportedly described in the *Chronicle* of Hydatius. This eruption, however, is spurious; it results from accidentally combining two unrelated passages dealing with the second year of Vespasian's reign (A.D. 70) and an eruption of Etna in 425 B.C., which appear juxtaposed in the *Chronicle* of Jerome (Olymp. 88), the immediate predecessor of Hydatius' *Chronicle*.

Second century A.D. Etna active at times (Florus, *Epitome* 1.11; Pausanias 3.23.9; Hyginus, *Fables* 152). The volcano was undoubtedly quiet in A.D. 125, when Hadrian ascended it (*Augustan History*, *Hadrian* 13.3). There is no justification for assigning a particular eruption to A.D. 165 (contrary to *Sartorius von Waltershausen* [1880]).

Third century A.D. Etna active (Minucius Felix 35; Solinus 5, 40; *Acts of Pionius* 5, February 1, Bollandists; *Acts of Patricius* 1, April 28, Bollandists). Solinus mentions two summit craters.

Fourth century A.D. Etna active (*Geographical Description of the World* 65, Mueller; Quintus Smyrnaeus 14.584–585; *Acts of Philip* 8, May 12, Bollandists; Servius, *Commentary on Vergil's Aeneid* 3.573; Pacianus, *Exhortation to Penitence*, Migne, *PL*, *13*, 1088–1089; Claudian, *Rape of Proserpine* 1.153–178; Diodorus of Tarsus in Photius, *Library* 223). Pacianus (writing in A.D. 379–395) does not report a specific eruption (contrary to *Alfano and Friedlaender* [1929]).

Early fifth century A.D. Etna active at times (Orosius 2.14; Olympiodorus in Photius, *Library* 80; Augustine, *City of God* 21.4; Salvian, *On the Governance of God* 7.16). In the first two decades of this century, Etna was comparatively quiet, according to Orosius and Olympiodorus. *Sartorius von Waltershausen* [1880] has wrongly claimed an eruption in ca. A.D. 420 on the basis of Solinus' (third century A.D.) description of Etna. *Imbo*'s [1965] eruption dates of A.D. 400 and 410 can be discounted.

Mid sixth century A.D. Etna active (Procopius, *Wars* 8.35.5). Procopius does not mention specific eruptions in the period A.D. 500–560 (contrary to *Sartorius von Waltershausen* [1880] and *Imbo* [1965]).

A.D. 604. The year given for this supposed eruption of Etna [*Imbo*, 1965] appears to be only a reference number to a text of Gregory the Great cited by *Sartorius von Waltershausen* [1880].

Euboea

At an unspecified date before the first century A.D., the Lelantine Plain on the island of Euboea, Greece, apparently erupted hot mud or lava (Strabo 1.3.16). Possibly the date was 199–197 B.C. (cf. Justin-Trogus 30.4). Hot sulfur springs are still active on the island.

Ischia

Fourth century B.C. Ischia had become less active after a long period of vigorous volcanism (pseudo-Aristotle, *On Marvellous Things Heard* 37). Knowledge of the island's volcanic activity goes back, apparently, to the age of the earliest mythographers (Pherecydes in scholium to Apollonius Rhodius, *Argonautica* 2.1211; Pindar, *Pythian Odes* 1.18;

TABLE 1. Catalog of Historically Recorded Eruptions of Mediterranean Volcanoes to A.D. 630

Year	Month/Day	Volcano	Intensity	References and Notes
B.C. 1500–1400		Thera	VL	See main text.
696–693 (or 456–453)		Etna	L	Thucydides 3.116; Ctesias in Photius, *Library* 72; Lycurgus, *Against Leocrates* 95–96; pseudo-Aristotle, *On the Cosmos* 400a 33–b6, *On Marvellous Things Heard* 154; Diodorus Siculus 20.101.3; Strabo 6.2.3; Conon (*Narratives* 43) in Photius, *Library* 186; Valerius Maximus 5.4; Seneca, *On Benefits* 3.37.2, 6.36.1; *Aetna* 606–646; Silius Italicus 14.196–197; Pausanias 10.28.4; Hyginus, *Fables* 254; Aelian in Stobaeus, *Florilegium* 79.38; Philostratus, *Life of Apollonius* 5.17; Solinus 5; Julius Paris, *Epitome of Valerius Maximus* 5.4; Claudian, *Minor Poems* 17. Lava reached, or nearly reached, Catania. Depictions on monuments are described by *Alessi* [1829]. On the date, see *Bergk* [1873].
ca. 500		Ischia		Strabo 5.4.9. The island experienced earthquakes.
479–475	winter?	Etna	L	Pindar, *Pythian Odes* 1.19–28; Aeschylus, *Prometheus Bound* 365–374; Thucydides 3.116; *Parian Marble*, epoch 52; Callimachus in scholium to Aeschylus 368; Favorinus in Aulus Gellius 17.10; [Favorinus in] Macrobius, *Saturnalia* 5.17. Lava may have flowed to the sea. On the date, see *Bergk* [1873].
ca. 470		Ischia		Pindar, *Pythian Odes* 1.18; Strabo 5.4.9
425	spring	Etna	L	Thucydides 3.116; Julius Africanus in George Syncellus, *Chronography*, Olymp. 88; Eusebius-Jerome, *Chronicle*, Olymp. 88; Orosius, *Against the Pagans* 2.18. Lava flowed in the direction of Catania. Sicily experienced an earthquake.
396	summer?	Etna	L	Diodorus Siculus 14.59.3. Lava flowed to the sea northeast of Catania.
ca. 350		Ischia	M	Timaeus in Strabo 5.4.9; *Aetna* 430; Pliny the Elder 2.203. The main peak, Epomeo, erupted. Earthquakes and a tsunami struck the island.
ca. 330		Vulcano	L	Aristotle, *Meteorologica* 367a2–9; Callias in scholium to Apollonius Rhodius, *Argonautica* 3.41. The earth bulged and broke; ashes went as far as Lipari and the Italian mainland.
276–239		Methana	L	Strabo 1.3.18; Ovid, *Metamorphoses* 15.296–306; Pausanias 2.34.1. The earth bulged to a height of 7 stadia (1300 m) and broke; lava flowed. On the exact location in the Saronic gulf, see *Meyer* [1932]; the volcano is probably Kameno Vouno (now 760 m in elevation).
269		Roccamonfina?	S	Orosius 4.4. A flame shot up and burned for three days near Cales.
217–216	summer?	Vesuvius?	VL?	See main text.
199–197		Thera	M	Posidonius and Asclepiodotus in Seneca, *Natural Questions* 2.26.4–7; Strabo 1.3.16; Justin-Trogus 30.4; Pliny the Elder 2.202, 4.70; Plutarch, *On the Pythian Responses* 399C; Pausanias 8.33; Eusebius-Jerome, Olymp. 145; Ammianus Marcellinus 17.7.13. A new island, Hiera, formed midway between Thera and Therasia in 4 days and had a circumference of 12 stadia (2200 m). Earthquakes occurred in Rhodes and elsewhere in the eastern Mediterranean. On Pliny's (2.202) probably mistaken date, see, for example, *Smith* [1870] under "Thera."
183		Vulcano	M	Livy 39.56.6; Pliny the Elder 2.203; Ammianus Marcellinus 17.7.13; Obsequens 4; Orosius 4.20; Cassiodorus, *Variae* 3.47. A new island (Vulcanello?) arose near Vulcano.
141		Etna		Obsequens 23
135		Etna	L	Lucan 1.43; Obsequens 26; Orosius 5.6. Lava and ashes were erupted.
126	before June?	Etna	L	Obsequens 29; Orosius 5.10. The summit erupted, and an earthquake occurred.

TABLE 1. (continued)

Year	Month/Day	Volcano	Intensity	References and Notes
126	June	Vulcano	M	Posidonius in Strabo 6.2.11; Pliny the Elder 2.203, 2.238; Eusebius-Jerome, Olymp. 163; Obsequens 29; Orosius 5.10. A new island arose between Vulcano and Panaria and caused a tsunami. On the location and on Pliny's (2.238) and Strabo's misleading dates, see, for example, Bunbury in the work by *Smith* [1870] under "Aeoliae Insulae."
122–121		Etna	L	Lucretius 6.639–646; Obsequens 32; Orosius 5.13; Augustine, *City of God* 3.31. Possibly also Cicero, *On the Nature of the Gods* 2.96; Seneca, *Natural Questions* 2.30.1; Hermogenes, *On Invention* 2.2, 3.12. Lava flowed from the summit to the sea; ashes partly buried Catania.
104		Vulsini	S	Obsequens 43. A flame shot up near Volsinii.
91		Ischia, Roccamonfina, or Vulsini	S	Pliny the Elder 2.199; Obsequens 54; Orosius 5.18. A flame shot up from the ground, with an earthquake. Aenaria (Ischia), Aesernia (Samnium), Aemilia (Modena), and Oenaria (Etruria) are possible locations; *Oudendorp* [1720] favors Aesernia. The Modena area, it seems, is generally nonvolcanic (but see Pliny the Elder 2.240).
50–49		Etna		Lucan 1.545–548; Petronius, *Satyricon* 122.135–136. Hot ash or lava flowed toward Italy.
44	March?	Etna	VL	See main text.
36	summer	Etna		Appian, *Civil Wars* 5.117
32		Etna		Dio, *Roman History* 50.8.3
A.D. 38–40		Etna		Suetonius, *Caligula* 51. Possibly this was not a true eruption.
46		Thera		Seneca, *Natural Questions* 2.26.6, 6.21.1; Pliny the Elder 2.202, 4.70; Dio 60.29.7; Philostratus, *Life of Apollonius* 4.34; Eusebius-Jerome, Olymp. 206; Aurelius Victor, *Caesars* 4; *Epitome of Caesars* 4; Orosius 7.6; Cassiodorus, *Chronicle*, Mommsen, *MGH*, *11*, 137. A new island, Thia, arose between Thera and Therasia. 2 stadia (400 m) from Hiera, and had a dimension (circumference?) of about 30 stadia (5600 m). An earthquake and a tsunami struck Crete. On Pliny's (2.202) probably mistaken date, see, for example, *Smith* [1870] under "Thera"; *Oltramare* [1929] states the particular day as December 31 (on the basis of Aurelius Victor's report of a concurrent lunar eclipse?).
79	August 24–25?	Vesuvius	VL	See main text.
202–203		Vesuvius		Dio 76.2.1–2
252	February 1–5	Etna	L	Isidore of Seville, *Hymns* 1, 2; Aldhelm, *On the Praise of Virgins* 32; Methodius the Confessor, *Oration on Agatha* 30–33; Petrus Thaumaturgus, *Oration on Athanasius* 3; Symeon Metaphrastes, *Life of Agatha* 18; *Acts of Agatha* (Latin) 15; *Acts of Agatha* (Greek) 14. These references can be found in the *Acts of Agatha*, February 5, Bollandists. This was a flank eruption, with earthquakes. Lava very nearly reached Catania.
417–425		Etna		Olympiodorus in Photius, *Library* 80
469–474	before Nov. 6	Vesuvius	VL	See main text.
505	November 9	Vesuvius		*Paschale Campanum*, Mommsen, *MGH*, *9*, 747
512	July 8	Vesuvius	L	Cassiodorus, *Variae* 4.50; *Paschale Campanum*, Mommsen, *MGH*, *9*, 747. Procopius (*Wars* 8.35.5–6) describes a great lava flow before A.D. 536. Possibly Cassiodorus, who seems to mention only historic ash flows, is describing the A.D. 505 eruption.
536	before March 24	?	VL	See main text. This was probably not a Mediterranean eruption.
626	October	?	VL	See main text. Possibly this was not a Mediterranean eruption.

Lycophron, *Alexandra* 688–690; Strabo 5.4.9, 13.4.6; Lucan 5.100–101; Silius Italicus 8.540–541; Servius, *Commentary on Vergil's Aeneid* 9.712).

First century to fourth century A.D. Ischia had become effectively extinct by the first century A.D. (*Aetna* 431). *Fazello* [1558], however, has listed, without giving sources, four eruptions of the main peak (Epomeo) during the reigns of Augustus (27 B.C. to A.D. 14), Titus (A.D. 79–81), the "fourth" Antoninus (one of the emperors between A.D. 180 and 222), and Diocletian (A.D. 285–305). (*Chevalley de Rivaz* [1859] incorrectly took Fazello's Antoninus to be the first Antoninus, A.D. 138–161.) Fazello must have inferred these four "eruptions" from references to related phenomena, like hot springs and earthquakes, by contemporary authors, for example, Strabo (5.4.9) in the first case and Valerius Flaccus (3.208–209) in the second. Fazello's sources for the last two eruptions have never been identified.

North Turkey

Circa 330 B.C. there was an eruption of "wind" from the ground near Heraclea in Pontus (Aristotle, *Meteorologica* 366b31–367a1). This was probably only an earthquake, for the region has not been volcanically active since the Tertiary period.

Thera (= Santorini)

For the third century B.C. to the first century A.D., Pliny the Elder's (2.202) text implies three eruptions of Thera: 237 B.C., 107 B.C., and A.D. 3 (or A.D. 19). The abundant testimony of other ancient authors, however, indicates only two eruptions and points overwhelmingly to the years ca. 197 B.C. and A.D. 46 (see Table 1). *Smith* [1870] nevertheless regards Pliny's total number of eruptions as correct and infers 67 B.C. for the date of the third eruption.

Vesuvius

Eighth century B.C. Alfano and Friedlaender [1929] mention a prehistoric, pumice-filled necropolis of this date at Sarno, to the south of Mount Vesuvius. The myth that Heracles and the gods battled the Giants on the Phlegraean Fields and thrust one of them, Alcyoneus, under Mount Vesuvius (Diodorus Siculus 4.21.5; Dio 66.22.2, 66.23.1; Philostratus, *Heroica* 1.4; Claudian, *Rape of Proserpine* 3.184–185) (while other Giants were thrust under Mount Etna and Mount Epomeo) perhaps preserves a dim memory of prehistoric activity of this mountain. A twelfth century B.C. date [*Imbo*, 1965] is only a guess.

611 B.C. Possibly an eruption of Vesuvius caused the rain of "pitch" that was reported to have fallen on North Africa between Tripoli and Cyrene in this year (Pliny the Elder 19.41) if the almost identical range of fallout after the famous eruption of A.D. 79 can be used as a valid analogy. An early eruption of Vesuvius might also explain Xenophanes' (sixth century B.C.) story of a solar eclipse that lasted a whole month (Aëtius, *Opinions* 2.24). However, these phenomena do not necessarily refer to an eruption of Vesuvius.

A.D. 80–120. Continuing mild activity of Mount Vesuvius after the great eruption of A.D. 79 (Martial, *Epigrams* 4.44; Statius, *Silvae* 4.4.79–85; Tacitus, *Annals* 4.67; Florus, *Epitome* 1.11).

A.D. 170–220. Continuing mild activity of Mount Vesuvius, with a smoke plume by day and a glow at night (Galen, *On the Healing Art* 5.12; Tertullian, *On Penitence* 12; Minucius Felix 35; Dio 66.21–22; Philostratus, *Heroica* 1.4; Solinus 2, 40). Galen makes no specific mention of an eruption in A.D. 172 (contrary to *Alfano and Friedlaender* [1929]) or ca. A.D. 203 (contrary to *Phillips* [1869]), although Dio records one in the latter year (see Table 1).

A.D. 220–350. No definite information about Mount Vesuvius exists for this period. The "eruptions" of A.D. 222–235 (Bunbury in the work by *Smith* [1870]; also *Alfano and Friedlaender* [1929]) are clear exaggerations of what Dio (66.21–22) actually wrote (and wrote before A.D. 229). The source for an "eruption" in A.D. 243 [*Mecatti*, 1752] has never been identified. Another eruption, falsely attributed to the lifetime of St. Januarius and dated A.D. 305 [*Majoli*, 1615], actually occurred much later, possibly in A.D. 685 (*Acts of Januarius*, September 19, Bollandists). The "eruption" of A.D. 321 is a consequence of two errors: first, a false attribution by *Mecatti* [1752] to the time of Constantine I and to Mount Vesuvius, in particular, of very general volcanic phenomena mentioned in a Sibylline prophecy which is quoted in Constantine I's *Oration* (18), and, second, a wrong assignment of the "eruption of the 16th year of Constantine IV" [*Capaccio*, 1771] to the corresponding year of Constantine I.

Late fourth century A.D. Continuing mild activity of Mount Vesuvius (Ausonius, *Moselle* 210; Pacianus, *Exhortation to Penitence*, Migne, *PL*, *13*, 1088–1089; *Epitome of Caesars* 10; Diodorus of Tarsus in Photius, *Library* 223). Pacianus (writing in A.D. 379–395) does not report a specific eruption during this period (contrary to *Alfano and Friedlaender* [1929]).

Fifth century to sixth century A.D. The claimed "eruptions" of A.D. 454 and 557 [*Mecatti*, 1752] are easily traced to errors in the dates, which should read A.D. 474 and 536. But it ought to be pointed out that the latter "eruption" has been inferred only from the mountain's premonitory rumblings in that year (Procopius, *Wars* 6.4.21–28). Jordanes' (ca. A.D. 550) (*Roman History* 143) reference to Vesuvius is only a stock description of the volcano.

Vulsini

Circa 500 B.C., "lightning" destroyed the town of Volsinii—legendary (Pliny the Elder 2.139–140; Tertullian, *To the Nations* 1.9, *Apology* 40, *On the Pallium* 2). Could this have been a volcanic eruption? Vulsini was not yet extinct (see Table 1).

West Africa

In the fifth century B.C. an isolated mountain of West Africa called the "Chariot of the Gods" was seen to be on fire (Hanno, *Periplus*; see also pseudo-Aristotle, *On Marvellous Things Heard* 37; Diodorus Siculus 3.53.6; Pomponius Mela 3.9; Pliny the Elder 2.238, 6.197; Arrian, *Indica* 43). This mountain has been variously taken to be one of the Atlas Mountains, or Mount Kakulima, or Mount Cameroon, among other possibilities [*Cary and Warmington*, 1929; *Carcopino*, 1944]. The various explanations of the fire have ranged from blazing grass fires to a volcanic eruption. The volcanic interpretation would fit only Mount Cameroon.

NO EVIDENCE IN EUROPE OF THE TAUPO ERUPTION

Recently, *Wilson et al.* [1980, 1981] claim to have found literary evidence that the great Taupo eruption in New Zealand (radiocarbon dated at about A.D. 130) occurred in,

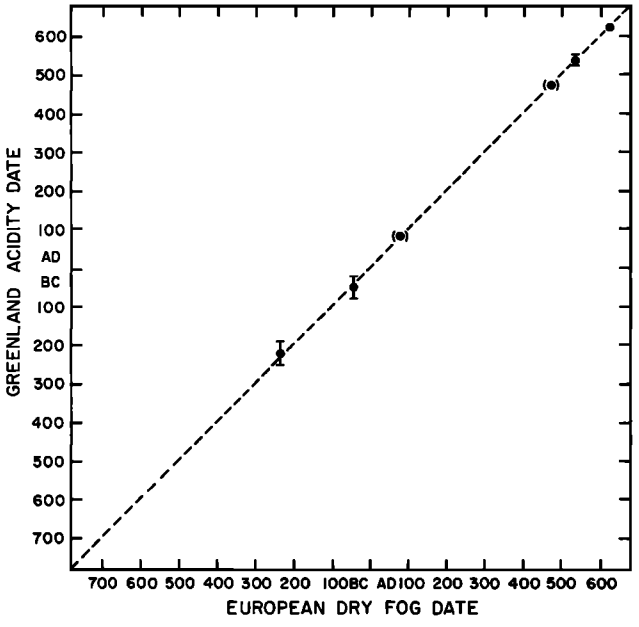

Fig. 1. Correlation between two independent indicators of large explosive volcanic eruptions, 735 B.C. to A.D. 630. These indicators are European historical dry fogs and the largest Greenland ice core acidity peaks. Two known large Mediterranean eruptions during the period A.D. 44–540, not covered by the available ice cores, are shown in parentheses along the 45° line.

or just before, A.D. 186. They cite in their favor two ancient Western sources and one ancient Chinese source. Only the Western sources concern us here. Herodian (*Roman History* 1.14.1) and, much less importantly, the *Augustan History* (*Commodus* 16.2) contain descriptions of unusual appearances of the sky during the reign of the Roman emperor Commodus (A.D. 180–192). Unfortunately, Wilson et al. have adopted an old English version (not identified) of the passage from Herodian in which the key word heteroi was mistranslated and a long gloss beginning "which was a token . . . " was added by the translator. A correct and full modern translation is given here: "Some stars shone continuously by day, others become elongated and seemed to hang in the middle of the sky" [*Whittaker*, 1969]. Since Herodian establishes a strong antithesis between hemerioi ("by day") and heteroi ("others"), the supposed evidence for elongated haze seen at dawn and dusk (i.e., in the daytime) disappears. A critical discussion of the available literary sources has already shown that the two passages in question probably refer either to the supernova of A.D. 185 or else to the bright comets and aurorae of the period A.D. 182–192 [*Stothers*, 1977]. Objections of a purely geological nature to the idea of a Taupo influence in Europe have also been raised by *Froggatt* [1981], essentially on the grounds that the volcano lies too far south (39°S). Counterarguments, however, have been given by *Wilson et al.* [1981].

Conclusions

The most important result of the present study, in our opinion, is the final availability of a reliable catalog of historically recorded volcanic eruptions and their associated effects, reported from the Mediterranean region before A.D. 630. In compiling this catalog from the original sources, we have been able to correct the errors and omissions of earlier catalogs and to increase by many times the number of ancient references now available for scientific scrutiny. Eruptions have been identified in the usual manner by direct reports of eruption columns, ash and pumice falls, nuées ardentes, lava flows, and volcanic cone alterations. But we have also introduced indirect evidence of a less familiar kind for the very largest (sometimes distant) eruptions, including dimming of the sun, atmospheric haze, solar haloes, and glowing skies as well as unusual earthquake activity, remote ash falls, atmospheric temperature decreases, and crop failures. No reports of unusually dark total lunar eclipses were encountered, however.

The eruption chronology is probably very nearly complete for those few events that had widespread geologic and atmospheric effects. There are at least seven of these events: Thera (fifteenth century B.C.), Vesuvius or some other northern hemisphere volcano (217 B.C.), Etna or some other northern hemisphere volcano (44 B.C.), Vesuvius (A.D. 79 and A.D. 472), and two northern hemisphere volcanoes (A.D. 536 and A.D. 626). The fifteenth century B.C. eruption of Thera has been discussed in detail by many authors. The 217 B.C. eruption of Vesuvius has not to our knowledge been noted before in the geologic literature; if real, it was the earliest historical eruption of the world's most famous volcano, although it need not have caused the dry fog of that year. The similarities among the ancient reports of this eruption, the one in A.D. 472, and the well-known A.D. 79 eruption support the conclusion that they were all large plinian events. The 44 B.C. eruption of Etna also seems to have been a large explosive event with widespread geologic effects and perhaps caused that year's dry fog. Similarly, major explosive events occurring somewhere in the northern hemisphere (north of 20°S) in A.D. 536 and A.D. 626 were undoubtedly the source of the atmospheric disturbances in those years. Probably a distant volcano (Rabaul, New Britain?) was responsible for the unparalleled atmospheric disturbance in A.D. 536.

Since the persistence of atmospheric veiling may provide a rough measure of the explosive magnitude of a volcanic eruption [*Lamb*, 1970], it is interesting to find that the eruptions of 44 B.C., A.D. 472, A.D. 536, and A.D. 626 produced approximately 9, 12, 18, and 9 months of veiling, respectively. There seems to have been associated with the veiling a protracted period of unusually cold weather, which drastically affected crop yields in those years. Unfortunately, the duration of the dry fog in 217 B.C. is unknown, and information concerning possible dry fogs in the fifteenth century B.C. and in A.D. 79 is lacking. In any case, similar consequences of very large explosive eruptions have been felt in Europe in modern times.

Another indication that these eruptions had widespread atmospheric effects comes from the presence in Greenland ice cores of marked acidity peaks around the years 260 ± 30 B.C., 210 ± 30 B.C., 50 ± 30 B.C., A.D. 540 ± 10, and A.D. 623 ± 3 [*Hammer et al.*, 1980]. These peaks are almost certainly volcanic in origin. Within the time intervals where our European dry fog data and the present Greenland ice core data overlap, there is a nearly perfect one-to-one correspondence (except for 260 B.C.) between these two independent tabulations of major volcanic years, as shown in Figure 1. A gap exists in the detailed ice core record between A.D. 44 and roughly A.D. 540; from our work, we predict that if and when detailed ice core data become available for this interval, peaks of acidity will be found in the layers corresponding to the years A.D. 79 and A.D. 472.

The one unidentified ice core signal at 260 ± 30 B.C. belongs to a very poorly documented period in history. Nevertheless, we point out that an exceptionally cold winter was registered at Rome in 270/269 B.C. (Augustine, *City of God* 3.17; Zonaras 8.6) and that the volcano at Methana, Greece, erupted between 276 and 239 B.C. (although the magnitude of the eruption is not known well). However, radiocarbon dating has revealed a number of other major volcanic eruptions in other parts of the world during this period [*Simkin et al.*, 1981].

We believe that our new and comprehensive study has demonstrated, much more forcefully than before, the usefulness of ancient historical records for determining the character of explosive volcanic eruptions in early historical times. A similar study of ancient Far Eastern literature would be most worthwhile for establishing the hemispheric effects of these eruptions and would possibly reveal evidence for explosive volcanic events unrecorded in the extant literature of the Mediterranean civilizations.

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