Washington, Henry Stephens, 1867-

On the possibility of assigning a date to the Santorini vases / Henry S. Washington.

[Princeton : Princeton University Press, 1894]

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(A. J. A. ix)

PAPERS OF THE AMERICAN SCHOOL OF CLASSICAL STUDIES AT ATHENS.

ON THE POSSIBILITY OF ASSIGNING A DATE TO THE SANTORINI VASES.

INTRODUCTION.—The vases from Santorini have been long known as among the earliest types of Greek pottery, and have always held a position of considerable importance in the history of Greek ceramics. Aside from any question of style or provenance, their importance is partly due to the general belief among archæologists, that it is possible, on geological grounds, to fix, at least approximately, the date of their manufacture. It has been suggested to me, as a geologist who has spent considerable time during the last few years in Greece in connection with the American School of Classical Studies, that it would be worth while to review the whole subject from a geological point of view, with the aim of determining what our geological knowledge may be in regard to the vases in question, and whether, or not, belief in the possibility of assigning a definite date, on geological grounds, is warranted by the facts of the case. Such a review seems the more important from the fact that this belief has assumed wide-spread proportions, the approximate date of 2000 B. C. being given (even in some elementary manuals) with all the appearance of being based on certainty.

Accordingly, the subject will be treated from a purely geological standpoint, such definitions and explanations being given as may seem necessary to render the discussion clear to the non-geological reader. I propose to begin with a brief geological description of the islands and of the volcanic phenomena involved in the question; next, to examine the circumstances in which the vases were found; and, finally, to discuss the question in the light of the facts so noted.

GEOLOGICAL DESCRIPTION.—By Santorini is understood a group of islands, the southernmost of the Cyclades, situated in lon. 25° 20′ E. of Greenwich, and lat. 36° 24′ N. On the map it is seen that the group is roughly elliptical in shape, with a major axis running generally north and south, of about 18 km., and a minor axis of about 16 km. The group is composed of a ring of three islands, with three channels separating them (the northern one being the deepest), enclosing an oval, land-locked bay, with three small islands in the centre. All around the group (on the outside), at a general distance of from three to five km., the water gradually increases to the depth of 100 fathoms and over. The circuit of this deep-water line is approximately of the same shape as that of the outer shore line of the group. Inside the large island ring, on the contrary, the gradient is much steeper, the hundred-fathom line running close to the shore. The water inside is of considerable depth all over the bay, and reaches its maximum of 213 fathoms (390 metres) at a point north of and not far from the small islands.

The largest island of the group is Thera, on the east side of the ring—a crescent-shaped island, enclosing the bay in the hollow of its western side, and bounding it partly also on the north and south. This island is of typically volcanic structure. In the first place, the inner concave side is extremely high and steep, rising almost perpendicular from the water's edge to heights varying from 60 to 360 metres, the average being about 200 m. From this high inner rim the land surface falls away quite regularly to north, east, and south, till it reaches sea level. In the second place, the structure of the inner cliffs, a striking feature which draws the attention at once on entering the bay, bears witness to the volcanic origin of the group. These cliffs show very many broad or narrow bands of black, red, yellow, and white rock, which, in general, run in a horizontal direction along its face. These bands, which are the ends of strata sloping down and out from the face of the cliff, parallel to the surface of the land above, are seen to be compact black lava, reddish *scoriae* (volcanic cinders), and light-colored tufa, which is a rather soft and crumbly rock, composed of the fine dust and ashes blown out of a volcano and cemented by the action of water and the atmosphere.

Such form, such structure, and such materials, prove conclusively that we have to do with a volcano. The only exception to this structure is the mass of Great St. Elias and Mesa Vouno, in the southeastern part of the island, which are composed of marble and schist, non-volcanic rocks, and which represent the original island, as it existed before the formation of the volcano, at the site of its activity.

The island of Therasia, the one on the northwest of the ring, though smaller than Thera, is of the same structure and composition: a high, almost perpendicular cliff inside, showing alternate beds of lava and tufa, with the surface sloping gradually down to the sea outside. The still smaller Aspronisi, in the gap between the southern point of Therasia and Cape Acrotiri on Thera, is also of the same character.

The smaller islands in the centre are three in number, excluding two rocky islets only a few yards square. As they are all due to historically known eruptions, and have very little connection with the subject under discussion, the description of them will be very brief. The oldest (that to the southwest) is Palaia Kaimeni, a narrow, rugged mass of black lava, 100 metres high, formed by an eruption in 197 B. C., and slightly enlarged in subsequent centuries. To the northeast is Mikra Kaimeni (71 metres high), formed by an eruption in 1573, a small but good example of a volcanic cone, with crater. Between these lies the largest of the three, the island of Nea (or Giorgio) Kaimeni, which owes its existence to two distinct eruptions, the first of which, in 1707, formed the cone of Nea Kaimeni (101 metres high), on the north. About the first of February, 1866, began a second submarine eruption, a short distance to the south of this, lasting till August, 1870, by which was created the cone of Giorgio Kaimeni (127 m. high), which finally was joined to Nea Kaimeni, forming, of the two, one island. This cone, when I saw it in the spring of 1893, was still giving out hot steam and sulphur vapors. This eruption aroused great interest in the geological world, and was studied with great zeal and care by many scientists, chief among whom was M. Fouqué, whose voluminous work [1] is the standard one on the whole group.

[1] *Santorin et ses Éruptions*, Paris, 1879.

VULCANOLOGICAL PRINCIPLES INVOLVED.—Having thus briefly sketched the structure and present condition of Santorini, we may rapidly review some of the chief vulcanological facts and principles which have a bearing on the geological history of the island. At the outset, a volcano may be defined as a generally more or less conical mountain of peculiar structure, situated at a point on the earth's surface where connection exists (or has existed) between the very hot and either actually or potentially liquid interior of the earth and its surface. As to the causes of volcanic action, little is known, and it is needless to enter into a discussion of them here. When, however, the channel of communication between the surface and the interior is open, there results, under proper conditions, the ejection of various materials: steam and gases of various kinds, hot water and mud, and, by far the most important, stony matter which goes to form the cone of the volcano. This last comes to the surface sometimes in the form of lava (molten rock), which is more or less liquid at first, but gradually cools, forming beds and masses of solid rock. Again, masses of rock already solid (such as the so-called "volcanic bombs") may be ejected; or, again, the solid or liquid forms of the rock may be so disintegrated from various causes that they reach the surface in the form of *scoriae* or cinders, *lapilli* (smaller fragments), or the still finer volcanic ashes, sand, and dust. The ejection of these materials may be, as will be seen later, either quiet—a simple welling out of liquid lava—or may be of various degrees of intensity, at times assuming the phase of explosions of almost unimaginable violence.

The typical volcanic cones formed by the accumulation of these materials may be divided into three main classes, according to the nature of the *ejectamenta* of which they are composed. There may be lava cones, made by successive streams of lava pouring out on the surface, such as are met with in the Sandwich Islands. Or, again, the cone may be made up chiefly of the finer fragmental materials, *scoriae*, *lapilli*, and ashes (so-called "cinder cones"), as at Monte Nuovo, near Naples. But the great majority of volcanoes are cones of a mixed type, composed of superposed sheets of solid lava, cinders, and tufa, which structure is generally further complicated by the presence of "dykes," *i. e.*, vertical sheets of rock

resulting from the filling up by melted material of cracks formed in the cone by the eruptive forces. Such a structure has been seen to exist in the outer ring of Santorini. Here have already been noted the superposed beds of lava and tufa, and on closer examination numerous vertical dykes are clearly seen cutting the beds exposed along the inner cliffs.

I shall now examine this last type of volcano and see more in detail what the structure of such a cone is. The more or less disintegrated material is blown out of the rent to a certain height and falls at a greater or less distance, resulting in the following structure. Starting from the orifice, the beds of cinders, etc., slope upwards and outwards on all sides, forming a funnel-shaped hollow—the crater; then, after attaining a maximum height, they slope downwards and outwards on all sides. The lava sheets are partly those that have flowed over the growing edges of the crater, and partly those that have been extruded from the flanks of the cone; in both cases following the slope of the cinder-layers beneath.

Now, in the outer ring of Santorini it is seen that all the beds slope down and *out;* there are none left that slope down and *in.* In other words, all the central, funnel-like part of the volcano has disappeared, and has given place to an enormous elliptical gulf or pit, measuring 11 by 7.5 km., and with a total depth, from the highest point of Thera to the greatest sea depth, of 750 m.; which means that in all more than 60 cubic kilometres of rock have disappeared. The dispersal of all this part of the original cone is explained, from many analogous cases in the history of volcanoes, chiefly by a tremendous explosion which blew off all the upper and central part of the cone.

As an instance, the familiar case of Vesuvius may be cited. Prior to 79 A. D., the cone of Vesuvius did not exist, but the encircling ring of Monte Somma was complete. Though it was suspected by some,[2] from the appearance of the rocks, that the mountain was of fiery origin, yet almost all tradition of an eruption had been lost. Suddenly, in 79 A. D., after a few preliminary earthquakes, a violent eruption began of showers of stones, ashes, and mud, and especially marked by a tremendous explosion, which destroyed all the southern half of the mountain, leaving Monte

[2] DIOD. SIC., IV. 21, 5; STRABO, V. p. 247.

Somma much as we see it to-day, the cone of Vesuvius being due to later successive eruptions of a more quiet character. A still more striking example is furnished by the volcano of Tomboro, on the island of Sumbawa, east of Java. In April, 1815, there took place an eruption lasting only six days, but which made up for its brief duration by its violence. This eruption is well known for the great explosion, or explosions, attending it, the greatest, indeed, on record, by which the mountain lost 1600 metres of its height, and a mass of *débris* estimated at 1400 cubic kilometres, was dissipated into the air, the island of Borneo, at a distance of 140 km., being covered with ashes. The tremendous outburst of Krakatoa, between Sumatra and Java, may also be recalled. After such well authenticated cases as these, which are only a few out of many, such an explosion as was necessary to produce the gulf at Santorini seems quite moderate. The structure and mode of formation of Santorini are, in fact, typical of a large number of volcanoes, and such a detailed description has been given in order that the non-geological reader, who is naturally unacquainted with all the facts, may see what data we possess for forming a quite clear idea of the geological history of the group.

This, in brief, is as follows. There first existed at the site of the present group a small island (St. Elias and Mesa Vouno) of metamorphic marble and schist. Near (and partially covering) this was formed, in the course of ages, a large volcano of mixed type, rising out of the surrounding sea and gradually growing by successive eruptions of lava and cinders, till finally an unusually violent paroxysmal eruption took place, chiefly characterized by an explosion which blew into the air all the upper part of the mountain, cracking the sides and thus giving rise to the three entrances into the bay. The scattered material was, of course, mostly lost in the surrounding sea, but some was deposited on the remaining slopes, where it can now be traced. This explosion was also, as suggested by Fouqué, perhaps accompanied by a sinking of the central part, resulting in an increased depth of the bay. At a subsequent period eruptive activity was resumed, though with greatly diminished power, giving rise to the small Kaimeni Islands in the centre of the bay; and at the present time the volcano may be said to be dormant.

THE VASE FINDS.—Having thus obtained an idea of the structure and mode of formation of the group, we may pass on to the circumstances under which the vases were found. Here I have used as my authority the third chapter of Fouqué's *Santorin*.

The tufa (or so-called *pozzuolana*), of which Thera and Therasia are partly formed, is known to be an excellent material for use in concrete or cement for submarine works, and for some years prior to the last eruption large quantities of it had been extracted and exported by the Suez Canal Co. for their own use. The process of extraction is very simple, as may be seen to-day, for it is still exported from the islands. Spots on the steep inner cliffs are selected where the tufa is of the requisite quality and in sufficiently thick beds, and this, being very soft and incoherent, is broken off with picks and crowbars and allowed to slide to the water's edge, where it is shovelled into the vessels waiting for it. The material was, at the time spoken of, chiefly obtained from the east and south cliffs of Therasia, and from near Acrotiri on Thera. In the course of these excavations rough walls were met with in the tufa, which, being common in the islands, passed without notice, till in 1866 Professor Christomanos of Athens heard of them, and, in conjunction with others, made regular excavations for them near the south end of Therasia. Other excavations were made shortly after by Fouqué as well as by MM. Gorceix and Mamet, in the neighborhood of the present village of Acrotiri on Thera.

These excavations resulted in the uncovering of walls built of rough (or in some cases hewn) blocks of pumice and hard tufa, cemented in places by a reddish mud of volcanic cinders, sticks of wood being also inserted here and there among the blocks.[3] The plans of the buildings of which these walls formed part are in some instances quite complete, door and window openings were to be seen, and in one instance the base of a column in the centre of a square room.[4] Among these walls were found numerous household utensils of the inhabitants, including a bronze saw,

[3] It may be of interest to record that when I visited Therasia, in the spring of 1893, and inquired for these walls, I was informed by the Demarch and others that they had all disappeared—either destroyed with the tufa cliff or carried off for use in modern buildings.

[4] For plans and details *cf.* FOUQUÉ, *Santorin*, cap. III. p. 94, sqq.

mortars and pestles, and mills made of lava for grinding grain, as well as numerous vases and vase fragments, some of the vases still containing carbonized barley and other seeds. Most of the vases were found inside the wall enclosures, but others were found back of and outside of them.[5]

The walls rested either on lava, as at Acrotiri, or on a bed of tufa, as at Therasia, and were covered with tufa, in some cases to a depth of 30 metres. Traces of the old soil were found near and below the walls, and in a few cases a similar layer was also encountered at some height above them, between the tufa beds. The walls were in almost all cases standing upright, some reaching a height of two metres, or even more.[6] All the space inside and outside them was filled with tufa, which covered and enclosed the vases and other remains.

The theory that these constructions were for sepulchral purposes was quickly disproved by their plans and by the objects found, as well as not found, in them. These show that they were in reality dwellings.

It has also been suggested that these buildings did not lie on the surface of the original soil, but were cave-like dwellings hewn out of the cliff, such as are at present in use in Santorini; this theory being chiefly supported by the presence of a layer of ancient soil above some of them. This view is shown to be false by the following facts.

Some of the walls were covered with beds of tufa so thin and

[5] Fouqué's book being large, expensive, and rarely found in archæological libraries, it may be of use to quote his own *résumé* of the principal facts in regard to the life of the primitive inhabitants, as revealed to us by these excavations (*cf. op. cit.* p. XVI): "These men were laborers or fishermen. They raised flocks of goats and sheep, cultivated the cereals, made flour, extracted oil from olives, wove cloth, fished with nets. Their dwellings were supplied with wooden timbers, and the walls were of squared stone. They made on the wheel vases oddly decorated and of characteristic forms. Most of their utensils were of stone, most commonly of lava, and others of flaked flint or obsidian. They were acquainted with gold and probably copper, though these metals were extremely rare among them. Wood abounded in the island, while now only a single tree (a palm) exists in the whole group. The culture of the vine, which is at present practised to the exclusion of all other agricultural labor, seems to have been unknown at this period."

It may be that the ancient name for this island, Καλλίστη (HEROD., IV. 147), or a tradition of it, dates from this epoch.

[6] Fouqué gives very little information on this point.

incoherent that the excavation of caves beneath them would have been impossible. The natural situation of the buildings, and the presence of window and door openings in the rear and side walls, disprove this view. Further, M. Gorceix discovered traces of a roof of tiles and earth laid on beams, and it may be added that the finding of pottery outside the house walls is against such a theory.

The layer of ancient earth in the tufa above the walls is easily explained as being the remains of soil formed on the material which buried the buildings and which was itself subsequently buried.

Having thus seen that the tomb and cave-dwelling theories are alike untenable, the only alternative and the simplest explanation is that these were houses built on the slopes of the original volcanic cone, and subsequently buried by the ejections during an eruption; the inhabitants abandoning, in alarm, their houses and such of their utensils as they did not, in their haste, carry away with them. This eruption must have been sudden, and, as Fouqué observes, judging from the upright condition of the walls, accompanied by few or feeble earthquakes—a rather remarkable fact, as the presence of wooden beams in the walls (a precaution still in use in many places against earthquakes) indicates their frequency at the time the houses were built. After the primitive villages were thus destroyed, other eruptions followed, covering them still deeper. This went on for an unknown period, till, one day, a violent explosion took place, the pent-up forces becoming suddenly too great to be withstood by the mountain mass above; and, since there was no other outlet, the result was the disappearance of a large part of the cone and the formation of the deep central bay. That this catastrophe took place *after* the ejection of the tufa beds covering the walls, is shown by the fact that these beds are cut sharply off along the inner cliff down to the sea level, exactly like the lava and tufa beds lying beneath the walls.

DISCUSSION.—Since, then, the pottery antedates the great catastrophe, it is evident that if we can establish a date for the latter we shall have a limit on this side for the date of the former. Realizing the importance of this, and seeing that the geological phenomena involved were so striking and definite, archæologists turned to the geologists for aid in solving the problem of the date

of the vases. Whether they were justified in this confidence—that is, whether geology, in our present state of knowledge at least, is capable of solving this special problem—it is the object of this paper to examine. M. Fouqué, who was not only the most eager investigator of Santorini, and the greatest authority on it, but who had also conducted excavations himself for the vases, was naturally the one most competent to deal with the question, and his opinion was most regarded and most authoritative. He accepted the task and gave an answer to the question, though expressing himself "with great reserve," and ending with the remark: *Ce qui seul est absolument certain, c'est que Santorin a été habité avant l'effondrement qui a produit la baie.*[7] As one may judge from these two remarks, his opinion of the arguments advanced by himself was probably not very high, and he evidently only brought them forward and published them as the best that one thoroughly conversant with the subject could bring.

This being the case, it is doubly unfortunate that his reserve has been forgotten by those who quote him, and that his provisional and hypothetical date has been given by non-geological writers with an assurance and a certainty which he himself would be the first to deprecate. It must, then, be remarked that what follows is by no means intended as polemical against M. Fouqué, whose weight as an authority on Santorini the writer would be among the last to dispute; but it is put forward as an impartial examination of the arguments advanced by him, and results, as the writer hopes he may succeed in showing, in their refutation. It is the writer's aim to make clear to the archæologist the real value of M. Fouqué's statements as geological arguments, and to put the question again on a safe and secure basis, though this involves leaving it as it was in the beginning—unanswered.

The arguments on which M. Fouqué rests his claim for a date of about 2000 B. C., and which are presumably the best, if not the only ones,[8] are two in number, and are to be found on page 130 of *Santorin*. After stating that the formation of the large island

[7] *Op. cit.*, p. 131. It may be remarked also that, in his *résumé* of our knowledge of the inhabitants and their pottery (p. XVI), he makes no mention of the date of the latter.

[8] Though giving the subject considerable thought, I have not been able to invent any others, nor have I met with others advanced elsewhere.

scarcely began before the end of the pleistocene tertiary (Glacial Period), the duration of its growth being not less than the whole of the quaternary (present geological period), which has already lasted certainly very many thousands of years, he formulates the first argument, which is here given in a slightly condensed translation: "Observations on the islands in the centre of the bay show that after the great catastrophe there was *certainly*[9] a long period of quiet. Then in 196 B. C. took place a new eruption, which produced Palaia Kaimeni, although this was added to somewhat by eruptions in the first centuries after Christ. A second period of relative calm filled all the Middle Ages, and it was not till after the fifteenth century that the eruptions resumed their frequency and energy, and formed new islets. The second period of calm having had a duration of about ten centuries, one can, without rashness, allow to the first a minimum duration of double this, especially when one compares the intensities of the volcanic phenomena, so diverse as they are, which they followed. On this line of reasoning the formation of the bay would go back to about two thousand years B. C."

The argument above is based on at least two assumptions which are not in accordance with facts. The first assumption is that the length of the period of repose following a volcanic eruption is proportional to the intensity of the eruption preceding it. Now, while it is generally true that "a long-continued or violent eruption is usually followed by a prolonged period of repose,"[10] yet the exceptions to the rule are many, and no fixed principle of the sort has ever been recognized, or even enunciated, by any of the great writers on volcanoes, such as von Buch, Scrope, Daubigny, Fuchs, Schmidt, or Dana. Lack of space does not allow the citation of many examples, but the following may be given to show the want of correspondence between the intensity of an eruption and the duration of the succeeding period of calm.

The best known case is that of Vesuvius. Starting from the most violent eruption of all, that of 79 A. D., we find the next great one recorded in 472, when the ashes were said to have reached Constantinople. During the next seven hundred years we find seven eruptions recorded, the last in 1139, when dust and

[9] The italics are mine.—H. S. W.

[10] JUDD, *Volcanoes*, p. 33.

stones were ejected for thirty days. This comparatively very feeble eruption was followed by a period of almost absolute repose lasting nearly five hundred years. At the end of this time the volcano seemed quite extinct; so much so that the plain at the bottom of the crater was used as a pasture-ground for cattle. In 1631 took place the most violent eruption known since that of 79, when seven streams of lava poured down the mountain side, one of them flowing over the buried ruins of Herculaneum. Since then the volcano has been in a constant state of intermittent activity, very violent outbreaks occurring in 1737, 1779, 1793 (which lasted about eighteen months), 1822 (when six hundred feet of the cone were blown away), and 1872. Here we find the most violent eruption of all followed by only four hundred years of repose, while a comparatively feeble eruption (1139) was followed by nearly five hundred years; and the second most violent outburst of 1631 was succeeded by a period of gradually lessening activity lasting 106 years, broken by the great eruption of 1737, which in turn was followed by a period of many and irregular eruptions. A similar tale is told by Etna, and other volcanoes furnish as striking examples, which are quite enough to disprove the first assumption.

The second assumption seems to be that the intensity of the first eruption (that of the great catastrophe) was about twice as great as that which produced Palaia Kaimeni, that is, if the periods of repose are directly proportional to the intensities of eruption, which must be assumed as approximately true (if any such assumption is made), since the construction of mathematical formulæ for the relation between periods of eruption and repose is, from the nature of the case, impossible. A glance at the map of Santorini will be quite sufficient to show that the first eruption was much more than twice as violent as the second. It will be remembered that by the first explosive eruption a mass of material amounting to over 60 cubic kilometres was blown into the air, while by the second was produced only a small island, which, even granting that it has lost considerable from its bulk by denudation, could not have been one-tenth the size of the former mass, and was undoubtedly much less. The mass of material moved is here used as a measure of the intensity of the eruption, but the

manner in which the force was manifested points the same way. So, on this basis, it being taken for granted that the first assumption is true, we should allow much more than twice as great a duration to the first calm period as to the second, and hence place the great catastrophe at a date much further off than 2000 B. C.

But there are two more fundamental and more fatal points of weakness in this argument. The first is that Fouqué seems to assume that volcanoes act in a more or less regular manner; in other words, that there is a sort of periodicity in their eruptions. But, as is well known to all who have studied the subject, this is by no means the case. Volcanoes vary as widely as possible in the violence of their eruptions, in the periods between two successive eruptions, and in many other ways. There are volcanoes, such as Sangay in Ecuador or Stromboli in the Lipari Islands, which have been in a continuous state of activity ever since their discovery, while there are others, as Skaptar Jökul in Iceland and Monte Nuovo near Naples, which have had, or are due to, only one known eruption, and ever since have been to all appearances extinct. Between these two extremes there are all gradations, including Mt. Epomeo in Ischia, which has had only four known eruptions, those of 470, *ca.* 350 and 89 B. C., and 1302 A. D., and Vesuvius or Etna, with their irregular and spasmodic eruptive periods. In fact, in the present state of our knowledge, we can find no law governing the outbursts of volcanoes, though many attempts have been made, and, so far as we now see, they can be called regular only in their irregularity. It is, of course, not implied by this that they are not subject to the physical laws of the universe, but the fact should be made clear that up to the present time, owing to various causes, partly to the great complexity and difficult nature of the phenomena, we have not been able to discover the laws that regulate the action of volcanoes, or to establish any periodicity in their eruptions. Hence all reasoning based on such laws may justly be put down as unsound and unsafe.

It might be added that, though the data are very similar to those in the case of Santorini, no geologist has yet attempted to fix the date of the great pre-Pompeian eruption of Vesuvius, which produced the steep encircling wall of Monte Somma, or of that eruption that produced the Val del Bove at Etna.

But the weakest point in this argument is found in the sentence: *La seconde période de calme ayant eu une durée de dix siècles environ, on peut, sans témérité, attribuer à la première une durée minima double de celle-ci, surtout quand on compare l'intensité si différente des phénomènes volcaniques auxquels ils ont succédé.* Here it is seen that the assigned date, after all, rests on a merely personal estimate, or, to put it perhaps more correctly, a guess. What other grounds exist for placing the first period at double that of the second we are not told, and it is very difficult to see what they are or could be. For the sake of making the argument complete and logical, they should have been given. As it stands, the argument is seen to be founded on a purely personal opinion, and is hence of little or no scientific value.

The second argument is as follows, an exact translation being given, since some of the details are important: "At the north point of Therasia, and on the part of Thera opposite, the pumiceous tufa is covered with a bed of red pebbles, about 15 to 20 metres thick, enclosing marine shells. On the east shore of Thera, near Kolambo, my learned travelling companion, M. de Verneuil, and I, observed the same fact. All these spots have therefore been, since the formation of the pumiceous tufa, for some time beneath the level of the sea, then raised by a probably slow movement of elevation. Now on the part of Therasia thus raised there exist ancient constructions with inscriptions which enabled M. F. Lenormant to fix their date at the fifteenth century before our era. These constructions were built at a time when the elevation was even more marked than it is to-day, since a part of them is at present below the sea level. Now the formation of the marine bed which supports them and its elevation, which are consequently prior to the eighth century B. C., required a duration of time which I do not fear to estimate at at least ten or twelve centuries. One falls back, then, for the age of the pumiceous tufa almost on the date which I have fixed upon above."

This argument, as given here by Fouqué, is rather vague and uncertain. The tufa is presumably that spoken of on page 248, where its age is merely given as prehistoric. As he speaks of apparently the same tufa occurring all over the surface of Thera, even on the top of Megalo Vouno, it is possibly due to the last

eruption of the large volcano, but nothing definite is said of the tufa mentioned in the argument.[11] The impossibility of fixing the date of any inscription at the *fifteenth* century B. C. will be recognized by every epigraphist, and the use of the word *quinzième* is evidently a mistake, as later on he uses *huitième*, and bases his date on this latter figure.

The argument then seems, in brief, to be this: Buildings of probably the eighth century B. C. were found resting on marine beds, above tufa formed prior to the great catastrophe, which have since been raised above sea level. Therefore, estimating the time necessary for the formation and elevation of these beds at twelve hundred years, the date of formation of the tufa was about 2000 B. C.

The weaknesses of this will probably be at once apparent. In the first place, we do not know when the tufa in question was ejected—it may have been thousands of years before the great catastrophe. Then, there is uncertainty in regard to the buildings, not only as to their actual date as shown by the inscriptions, but their date relative to that of the marine beds, as it is impossible to say how many years elapsed between the elevation of the beds and the erection of the buildings. Next, subsidence and elevation may have taken place since their construction, as happened at the temple of Serapis at Pozzuoli; and so it is possible that the so-called marine beds were submerged beneath the water and covered with barnacles since the erection of the buildings. Last of all, and the most fatal weakness, is the estimate of ten to twelve centuries, which tallies so closely with Fouqué's other estimate. It is well known to all geologists that to estimate the time necessary for the deposition of any given bed is almost impossible in the majority of cases, and very uncertain even in the most favorable circumstances. We cannot be sure that the conditions always remained the same, and every

[11] Two discrepancies should be noted. The pebbles which are here called *rouges* are described as *cailloux roulés* on page 248; probably the latter adjective should have been used in the former place. On the same page, he says that at many points along the north shore (of Thera) there are cliffs composed of the *débris* of this pumiceous tufa, and "at the same time there are found these rolled pebbles . . . . and blocks of lava with scopulas and barnacles adhering to their surface." Here there is not mentioned a regular bed such as is spoken of on page 130.

change in the conditions under which a bed is formed necessarily changes the time of its formation. Then, again, elevation and subsidence are phenomena whose regularity we cannot be sure of; they may be either slow or rapid; and in this case no figures are given which enable us to form any idea of the rate of elevation, and, from the nature of the case, it is probable that no figures can be given.[12]

So it is seen that this argument, like the first, depends largely upon a purely personal opinion and estimate, unsupported by either facts or figures, and is hence comparatively valueless. Both these arguments, in fact, show signs of having been written hurriedly, and without having received from their author the thought and attention which were due them.

And now that we have seen the unreliability of both these arguments, which are all that have ever been brought forward in support of a date (on geological grounds) for the vases, it is pertinent to ask the question: Can geology solve this problem? In the present state of our knowledge, and, so far as one can see, for a long time to come, the answer must be No. It must be borne in mind that we are here dealing with a set of phenomena most uncertain and irregular in their action, the direct observation of which is most difficult, if not impossible, and that the science of vulcanology is still in its infancy. One might almost as well ask a meteorologist to tell in what year a given oak tree was blown down, when no meteorological records of the region had been kept, except those of a few storms, since the event. So, however regretfully, geologists must, for the present, withdraw from the attempt to settle the question of a date for the pottery of Santorini. It is possible that the accepted date of 2000 B. C. may be right; geology does not deny it. But my plea is merely against the acceptance of the date as definitely, even though approximately, established on geological grounds, when to give a definite solution of the question is, as we have seen, beyond the powers of a geologist. Such a proceeding does far more harm than good to both sciences; and the establishment of a date for the Santorini vases on such an uncertain and illogical basis would surely, in the end, prove injurious to the science of Greek ceramics.

[12] Fouqué admits this uncertainty when he says that the movement of elevation was *probablement lent*.

PLACE OF MANUFACTURE.—In conclusion, as geology has been shown to be unable to answer one question put to it, it is only fair that an example should be given where it, and it alone, was able to solve an archæological problem, and thus to show that it may be of great value to its sister science. This example is furnished by the same Santorini vases we have just been discussing.

It was a matter of some importance and interest to establish the place of manufacture of the vases; whether they were imported into the group of Santorini, and, if so, whence, or whether they were of native manufacture. There being no clay suitable for their manufacture found at the present day anywhere on the group, it was at first thought that the vases must have been imported. But M. Fouqué had the happy idea of examining fragments of the pottery by the same methods as are employed for the examination of rocks. The process consists in grinding the fragment with emery on iron and glass plates till it becomes thin enough to transmit light, when it can be easily studied under the microscope by the usual petrographical methods.

In all the vase fragments thus studied, he found numerous minute fragments of volcanic rock and minerals, which could be identified with certainty as derived from Santorini itself, and, not only that, but from definite parts of the group; for the Santorini lavas, like those all over the earth, have their own small peculiarities, and can, in many cases, be easily recognized. Besides these mineral fragments, he was able to identify various organic remains—foraminiferae, diatoms, and sponge spiculae, of different genera—some of fresh and others of salt water origin. From such data he drew the following perfectly safe and logical conclusions:

1. That all the pottery was made in Santorini itself.

2. That the clay of which it was made was taken from a bed situated where the sea had access to it, and, further, where fresh-water streams brought to it detritus from all the rocks of the southern part of Thera.

3. That this clay bed is now either destroyed or covered by the sea, but that it was probably situated in a valley between the southern part of the present Thera and the original central cone.

HENRY S. WASHINGTON.

Venice, Italy, June 18, 1894.

OVERBECK'S

TRACTS

1

EARLY

GREECE

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