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The following paper was read by Professor HUGHES:

HERCULANEUM.

INTRODUCTION.

I first visited Herculaneum in 1881, and in the same year I read a paper to the Chester Natural Science Society, in which I gave a short account of my examination of the site, pointing out that the city was buried under a thick deposit of dust and ashes, partly showered down during the eruption of A.D. 79, and partly swept into the hollows by the torrential rains that accompanied the outburst, and that this was in places now converted into hard tuff, and in places buried still more deeply under the ashes, and, in the suburbs, overlapped by the lava of later eruptions.

In 1903 I brought before the Archaeological Institute[1] the result of that and later researches which I had had opportunities of carrying on, and endeavoured to make out more precisely from the character of the material in which the ruins are buried, from the physical geography of the district, and from historical notices, what must have been the position of the city and the shape of the ground on which it stood. I further collected what evidence I could as to the circumstances of its entombment, and incidentally such references as I came across respecting the character of the city and the prospects of there being historical and artistic treasures still buried in the ruins of the town and of the villas outside its walls.

I gave examples of forests and buildings buried in various ways in order to emphasize my contention that a knowledge of the manner in which nature works under different conditions is of the first importance for those who are trying to unearth

[1] *Archaeological Journal*, Vol. LX. 1903, No. 239, pp. 255—267.

the relics of the past on such a site as Herculaneum and to read the history recorded by them.

As the outcome of all my enquiries, I came to the conclusion that the further exploration of Herculaneum was not impossible, or even so difficult a task as was generally supposed, and I offered some practical suggestions as to the mode of procedure.

The President, in some kind remarks upon the paper, asked whether the Institute should approach the Italian Government on the subject, but I thought that we should best promote our object if we first discussed the questions thoroughly from the scientific point of view, believing that the practical engineering difficulties could be approached with greater advantage when accurate scientific data had been obtained, and that there were financial questions which must wait upon time.

Next year, however, the matter was put upon an entirely different footing by Dr Waldstein, whose experience and reputation as an explorer, and whose influence with illustrious and powerful personages commanded immediate attention to his proposal that the work of exploration of Herculaneum should be taken up as an international question, and I am sure we all rejoice to learn that his efforts are now likely to be crowned with success.

It does not fall to the lot of all to be engaged in the fascinating work of unearthing the buried records of remote ages, but many who cannot take an active part in it are watching with interest the results achieved.

I have recently had an opportunity of re-examining the area and discussing the subject with our Consul General in Naples, and with Commendatori Boni and Lanciani, in Rome; and I have thought that it might interest our Society to lay before them the evidence which I have collected and arranged. I am also able to shew a few sketches and photographs taken by my wife during some of our later visits.

If we propose to unearth some of the treasures of art and literature that lie buried under the slopes of Vesuvius, if we want to study the public life and the home surroundings of the people who lived in its villas and villages and towns surely our

first enquiry must be—what are they buried under and is it all material of the same kind? Must we burrow under sheets of lava or slowly chisel away vast masses of naturally formed cement? Or may we hope to be more fortunate and, in places, have only to shovel and sweep away soft unconsolidated dust to disclose the statues and pictures, the libraries, the ornaments and ordinary domestic appliances, and perhaps the very bodies of some who were suddenly overwhelmed in the midst of an active life?

We must see what can be made out from history and tradition as to the nature of the catastrophe. If earthquakes played the principal or even a large part in the destruction of the buried buildings we must expect that the objects interned must have been subjected to very different conditions from those which would have prevailed if the whole area had been quietly covered by gently falling dust and ash. If a fiery stream of molten lava flowed over it our chances of recovering any well preserved relics would be very small, and the difficulties of excavation would be hardly less if the buildings were filled with mud which had rapidly consolidated into a hard concrete.

Traditions, except where they have been placed on record by almost contemporary writers, seldom help us much, for men have but short memories for even great catastrophes, although the memorials of them may be perpetually before their eyes. A castle, a camp, a volcano may suggest to the learned fierce and terrible episodes of bygone ages, but how soon all recollection of the date or circumstances passes from the minds of the dwellers in their neighbourhood.

So we find that little is known of the history of Vesuvius previous to the earthquakes of A.D. 63 and 64 and the eruption of A.D. 79, and little trustworthy information can be gleaned upon the spot respecting even the later outbursts. Until quite recent times but few accurate observations have been taken and few of the circumstances have been recorded.

Still we have some evidence—from examination of the site, from the results of excavations, from travellers' letters, and

incidental mention in history, and I will now try to put together what I can find out respecting the early history of the district; the shape of the ground previous to A.D. 63; the position and character of the town; the earthquakes of A.D. 63, 64; the eruption of A.D. 79; eruptions later than A.D. 79; the results of excavations; and the possibilities of future exploration.

We infer, from the silence of ancient writers as to any eruptions in their time or any tradition on the subject, that Vesuvius had been quiescent for ages. Besides that, the descriptions of the mountain tell us the same story more plainly. Before the great eruption of A.D. 79 the bottom of the old crater had become a sunken, sheltered piece of more or less flat ground, covered with vegetation—a spot frequented by wild boars and other animals—and an almost inaccessible fastness which, in the Second Servile War long furnished a safe retreat to Spartacus and his band.

Those ancient writers were not unobservant, uneducated men but the leaders of the literature and science of their time, men whose works have become classical for lucidity and accuracy. Many of them knew that there had been volcanoes in districts where in their time they had long ceased to show any signs of activity and recognised on Vesuvius the ashes of ancient eruptions. Aristotle[1] (B.C. 384–322) speaks of the outbursts which reduced the whole of the town of the Liparaeans to ashes and reached some of the towns of Italy.

Vitruvius[2], a military engineer during the first half of the first century (B.C. 100–44) who was probably a native of Campania, mentions the tradition that flames had at one time been seen coming out of the crater.

"Non minus etiam memoratur antiquitus crevisse ardores et abundasse sub Vesuvio monte et inde evomuisse circa agros flammas."

Tacitus[3] A.D. 55–117, mentioning the eruption of Vesuvius

[1] *Meteor.* II. vii, viii.
[2] Lib. II. cap. 6.
[3] *Hist.* lib. I. cap. 1.

in the reign of Titus, seems to hint likewise at former eruptions:

"Iam vero Italia novis cladibus, vel post longam saeculorum seriem repetitis, afflicta, haustae aut obrutae fecundissimâ Campaniae orâ et urbs[1] incendiis vastata."

Florus[2], in the beginning of the 2nd century A.D., speaking of Campania, calls it the most beautiful region not only of Italy, but of the world—with its noble harbours and its vine-clothed mountains, among which Vesuvius, the loveliest of them all, emulates the grandeur of Aetna's fires, or as Timaeus, quoted by Diodorus Siculus, calls it the hill which aforetime breathed forth "fire unapproachable" like Aetna in Sicily[3].

Pompeii, spoken of by Tacitus as that "celebrated city of Campania," increased in extent and wealth, while Vesuvius caused no more uneasiness than do the extinct volcanoes of central France at the present time. Sarnus still ran as Sarnus had always run. According to Strabo it was the traffic route for Nola, Nuceria, and Acerrae. Up it, as Livy tells us, the galleys of Cornelius sailed as far as Pompeii at any rate, and there had been no change in the physical geography of the district sufficiently striking to have found mention in any of the works which have come down to us. Herculaneum however remained a small town, but it is not only from the notices in ancient writings that we may hope to learn its story. We must also decipher correctly the record of the rocks, and at every step in the progress of excavation our interpretation of the mode of formation of the ground in which we are working must guide our choice of direction and our methods of further research.

If we know what are the causes and effects and the normal development of volcanic activity we shall be better able to read and understand the fragmentary records of the destruction and renovation of the cities on the southern sea from which it is now proposed to lift the veil with which they have been gently but closely covered for hard on 2000 years.

I propose therefore to give a short history of the volcano

[1] *i.e.* Rome. [2] *De Bell. Samnit.*, lib. I. cap. 16.
[3] Diodorus Siculus, IV. 21. Pindar, *Pyth.* I. 40.

which has on the one hand so often spread desolation and death over some of the fairest and most thickly populated regions of the earth, but on the other hand has sealed up and preserved for the contemplation of posterity a truthful record of a brilliant past.

Once there was no volcano there. A shallow sea, teeming with the varied life of a southern clime, extended over the Phlegraean Fields and up to what then represented the Apennines. No man was there: what man's precursors were does not now concern us.

The mud settled down quietly in that area of inappreciable tides, save when the wind waves churned up the shallow shore. The ground-up shells and corals furnished more lime in one place, the mountain torrents brought down more clay in another. All these marine deposits have been depressed over the area with which we have now to do: in the encircling hills the margin of the basin may be seen.

But we are still in touch with them, for in Pompeii and Herculaneum, and over all the surrounding country, fragments of baked loam and limestone are found, which have been torn from the rocks through which the explosions found a vent, and shot out of the crater during eruptions. These are the buff and grey stones carved into bracelets, brooches, and other ornaments, and sold as lava.

The question arises therefore whether we might in our excavations come upon the old sea floor out of which the volcanoes rose, and find that some of the buildings were erected upon it, but this is most improbable. From the lie of the rocks and the results of excavations it is practically certain that all the towns and villages round Vesuvius were built upon volcanic beds, and we shall see by and by what considerations generally determined the choice of a site.

All the area was covered with volcanic ejectamenta in far off prehistoric times. The earthquakes of A.D. 63 and following years were only a fresh start in a long sequence of periods of alternate quiescence and activity, and it will help much to understand the great episode of 63–79, and to interpret correctly

the descriptions given if we get some idea of the usual course of events in the development of volcanic phenomena and its application to the Phlegraean Fields.

The scene of volcanic activity has always been shifted from one area to another over the face of the earth. So within the limited volcanic district round Vesuvius the chief centres of eruption have been now here now there. At one time Monte Epomeo in Ischia was the focus, then Vesuvius took it up, or Monte Nuovo.

The history of many of the later eruptions of Vesuvius is known, and rough estimates have been made of the amount of material thrown out, from which it is clear that if we peeled off the accumulations of only the last 2000 years there would be a very appreciable difference in the seaboard of the Bay of Naples, though the general appearance of the coast and of the great mountain which forms its background would be much the same. But the face of nature has not been so far changed that we cannot arrive at a fairly consistent idea of the position and surroundings of Herculaneum before the great catastrophe of A.D. 79, in which it was overwhelmed.

Ancient Geography of the District.

Let us then enquire what was the form of the ground before the eruption or eruptions which have buried the ancient soil with all that was on it or in it? Surveys are of very recent date, but there is a good deal of scattered evidence from descriptions or incidental remarks in ancient writings, from direct observation during excavations, or inferences from an examination of the surface, as to the geographical features and general appearance of the district before it was changed by the volcanic outbursts which, not once or twice, but repeatedly, swept away the growth of nature and the works of man and left wide regions a waste of cinders.

At the time of the great earthquakes of A.D. 63 and 64 and the eruptions of A.D. 79 the general aspect of Vesuvius and the bays below it must have been much what it is now. For the building up of the land by the accumulation of lava and ash

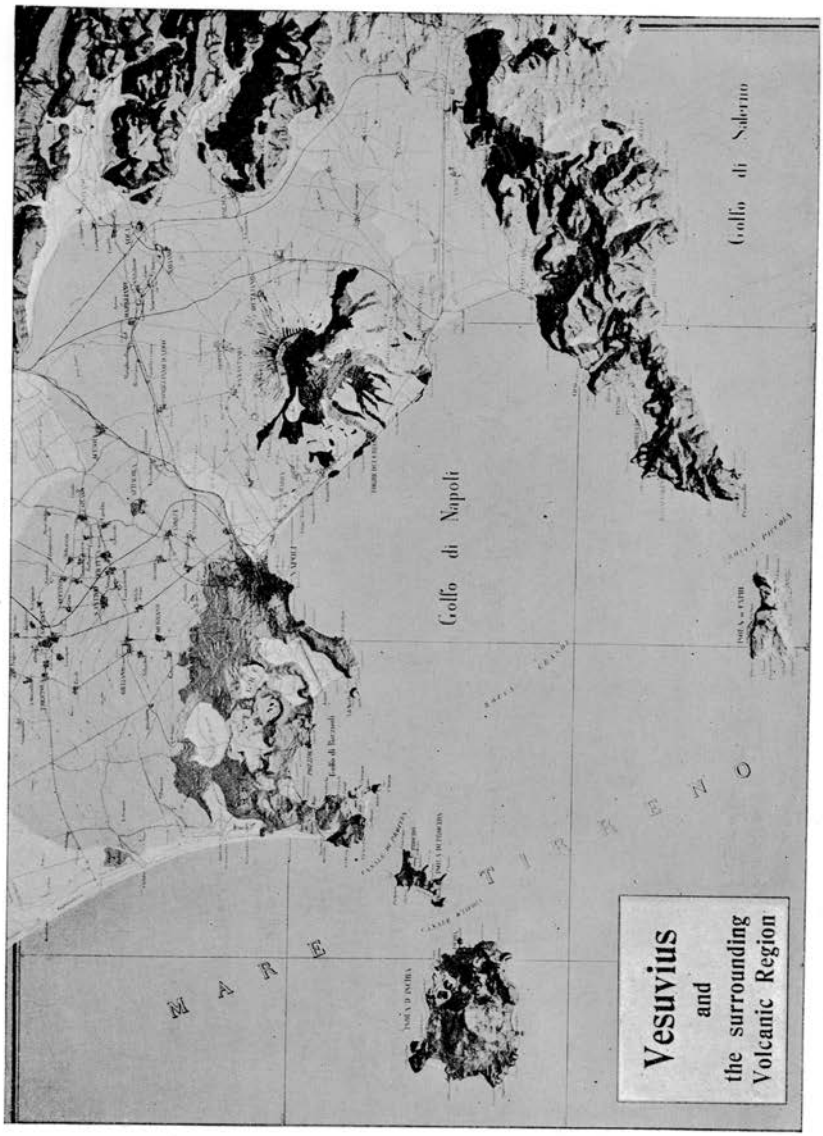
had gone on through long ages, although, just before the great catastrophe that concerns us most, there had been a long period of inactivity.

Any one standing on the higher ground near Misenum (see Map, Plate I)[1] can hardly fail to see that the surrounding area consists of a number of circular basins with broken rims, over the lower parts of which the sea has sometimes flowed, while in other cases, as in that of the solfatara or Avernus for instance, the basin has not been sunk low enough to let the sea run in. These are obviously submerged craters. As we extend our view we see reason for suspecting that the movements of depression, of which these drowned volcanoes are evidence, extended over wide circular areas, so that, although we may be unable to call the submerged basin an old crater, because the margin is in places made up of sedimentary rocks, still the areas of subsidence are obviously so directly connected with the volcanic history of the district that we cannot regard them as anything but basins of volcanic settlement, as the true craters are basins of volcanic explosion. A settlement very naturally follows from the abstraction of immense quantities of solid material from beneath the surface, and readjustments are continually taking place where the upper crust of the earth is in such an unstable condition. So we observe upward as well as downward movements recurring over such areas. The changes of level indicated by the columns of the baths which used to be known as the temple of Jupiter Serapis near Pozzuoli, have been often described, and recently a valuable contribution to our knowledge of the submerged Greek and Roman foreshore, near Naples, has been made by Mr R. T. Günther[2].

We have also to bear in mind that the basins have been filled, and inequalities levelled by ejectamenta, of which a large proportion consists of pumice, scoriaceous lava, and ash of small specific gravity, and is therefore easily transported by streams and dispersed over the sea bottom.

[1] Reduced from the photograph of a model kindly given to me by Signor Aureli.

[2] *Archaeologia*, Vol. LVIII. 1903, p. 499.


Golfo di Napoli
Golfo di Salerno
M A R E T I R R E N O
Vesuvius
and
the surrounding
Volcanic Region

The floor, out of which the volcanoes of the Vesuvian area rose, is known to have been as new as Pliocene times at any rate, for the baked fragments of limestone and loam hurled out of the crater often contain fossils sufficiently well preserved to fix the geological age of the bed.

The whole volcanic group however has risen out of a kind of basin of depression in the Tertiary rocks, the rim of which is represented by the lower Apennines and by the continuation of the same range of hills at the back of the Sorrento district to the Gulf of Salerno and so round to Capri.

The hill on which the Convent of Camaldoli stands is a mass of volcanic ejectamenta. The trachytic lava which occurs near the foot of the hill near the village of Pianura is largely quarried, as it is valued on account of its hardness and durability, and is used in Naples for pavements, steps, &c. It is locally known as *piperno*, which must not be confounded with *peperino*, the grey tuff from the Alban Hills so commonly used in Rome for building purposes.

There is not much evidence as to the depth of these marine Tertiary beds below the volcanic deposits.

Serao, a celebrated physician of Naples, who wrote an account of the eruption of Vesuvius in 1737, says that in sinking a well at the Convent of Dominican Friars (Madonna del Arco) a bed of lava was discovered at a depth of one hundred feet, and soon after another, so that in less than three hundred feet the lavas of four eruptions were found.

We are not likely to get to the bottom of the volcanic deposits anywhere on Vesuvius; the ancient cities and settlements are all, as far as we can trace them, upon ancient lavas and tuff. See pp. 36, 37.

What is taken as the base of Vesuvius is defined by a somewhat arbitrary line as it tails off to the south-east beyond Pompeii, and its spurs are tangled among the smaller hills of the Phlegraean Fields on the north-west. But a circular area about thirty miles in circumference will include all that we have to consider in any description of the mountain. Its height also, which we may call in round numbers four thousand feet, changes from the time of one survey to another. Out of

this base the great mountain rises, giving in outline or section a truncated cusp.

As the inhabitants of Herculaneum saw it, the rim of the crater was complete on the south side also, and corresponded in height to the Monte Somma, which is part of the ancient rim on the north and west. The great eruption of A.D. 79 broke down the southern rim of the crater which is now represented on this side by the Pedimentina—a small inconspicuous ridge at a much lower level, which just enables us to trace what was the form and extent of the crater, and nearly coincides with the southern base of the new cone. Of course in restoring the outline of the crater, we must carry the southern side up, not vertically, but with a long slope rising to the north and so far limiting the actual southern extension of the crater. The circumference of what remains of the ancient crater is about seven miles. This great crater of the first century A.D. was approximately in the centre of the conical mountain mass, but the small crater, which has been built up in more recent times within it, has not risen in the centre of the inside of the old crater but at the southern end of it, leaving a great flat lunette-shaped plain, known as the Atrio del cavallo, between the new cone and the Monte Somma.

These variations had their effect in determining to some extent the point of eruption and the direction of the lava flows, seeing that since the eruption of A.D. 79 Monte Somma has remained a mighty barrier which has restrained all subsequent efforts to break out on the north and west side of the crater and has turned the lava flows down on the east and south. The constant height of the Monte Somma and the variations in the height of the newer cone must be taken account of in all numerical estimates of the heights, distances and positions of the highest points of the mountain relatively to one another and to the surrounding towns.

I propose as we go on to try to reconcile early descriptions of the district and accounts of episodes connected with it, with what we know of its geology and of the normal sequence of events in this volcano during its periods of activity.

THE CRATER.

For instance, if we examine the interior of the great crater as represented by Monte Somma, we shall find its precipices traversed by dykes, which are the tongues of lava which got cooled in the cracks and fissures into which they were injected from the seething molten mass that once stood in the great crater at any rate up to the level at which we see the dykes. Some of them reached the exterior of the cone and were once the source of lava streams which helped to build up the mountain. Since A.D. 79 however the lava would flow over the Pedimentina long before it could rise to the level of the higher dykes of Somma.

From the descriptions given we may infer that there was a flat area at the bottom of the crater surrounded by an almost unbroken rim. But at one place the rim was cracked and fissured so that there was a path by which the interior could be reached. This was seized and guarded by the troops of Clodius Glabrus the praetor, when the crater was occupied by Spartacus and his band. The story has been supposed to imply that the crater was precipitous on the outside as well as on the inside, and that Spartacus and his men, having somehow got to the top of the rim, were let down by ropes made by tying wild vines together. We can hardly suppose that after it had been exposed for ages to the crumbling action of the weather the exterior of the crater can have been precipitous all round. Perhaps it was only here and there that it was so steep, and a steep place was chosen as being for that reason unguarded. But a much simpler explanation and one more consistent with what we know to have always been the condition of this and similar craters is that the descriptions do not imply that Spartacus and his men dropped over the rim of the crater down a precipice on the outside, but rather that by the help of something like rope ladders or chains, constructed out of the long trailing stems and branches of the vine, they made their way out through the deep chasms in the broken wall of the crater ("per fauces cavi montis, vitineis delapsi

vinculis, ad imas ejus descendere radices[1]"). Clodius guarded the only easily traversed way but never supposed it possible that Spartacus and his followers could find their way out through the rough and apparently impassable cracks and fissures deep down below the obvious path.

If the fault, of which there is some evidence on the north-eastern side of the valley of Somma and St Sebastiano and along the ridge of Ottajano, had breached the rim of the crater, that is the sort of place that would have afforded access to the interior of the crater, and through this gap, may be, the path was found or made; but, among the ruins of shattered rock there would be deep and dangerous chasms into which Spartacus and his band descended and found their way to the outside.

Geographical Features of Site of Herculaneum.

Although tentative exploration is what suggests itself as the wisest method in the case of Herculaneum rather than a scheme of simultaneous uncovering of large areas, still we may well be guided in our selection of sites for trial, and assisted in the interpretation of such evidence as may from time to time be forthcoming, if we can arrive at clear views respecting the physical geography of the district when Herculaneum was a seaport accessible from all the most frequented parts of the coast, with a safe harbour for the yachts and merchant vessels, and the ships of war of those days.

We must try to make out where was or where was likely to have been in those days the crowded town, and where were the rich terraced slopes of the gardens of the wealthy, luxurious and often highly cultivated people who, we know, had villas in the country round the town.

If we look at Vesuvius from the sea or from any distant point of view on land, or even from the top of the mountain itself, we cannot fail to be struck by the smoothness of the outlines. And yet when we examine the details we find that the mountain

[1] Florus, lib. III. c. 20.

has been built up not only by ashes but also by streams of lava which ran within sharply defined limits and ended abruptly along their margin, as well as at their end. The lava is festooned into every possible twist and curl as the flow was arrested by cooling, or as the molten mass below, still moving on, forced the cooled surface forward and broke it up into rugged heaps of cinder.

These solidified rivers of lava left hollows between them down which the next outburst of lava found its way. So that the safest place to build on was the ridge of old cooled lava, as the next flow would certainly take the lower ground, on either side of it. Thus the Observatory is perched on such a ridge, and later flows have run down on each side and nearly surrounded it.

What is suggested by the long tongues of lava creeping down the mountain side is proved by actual observations.

Sir William Gell[1] points out that Pompeii was built upon a bed of lava which stretches out into the plain.

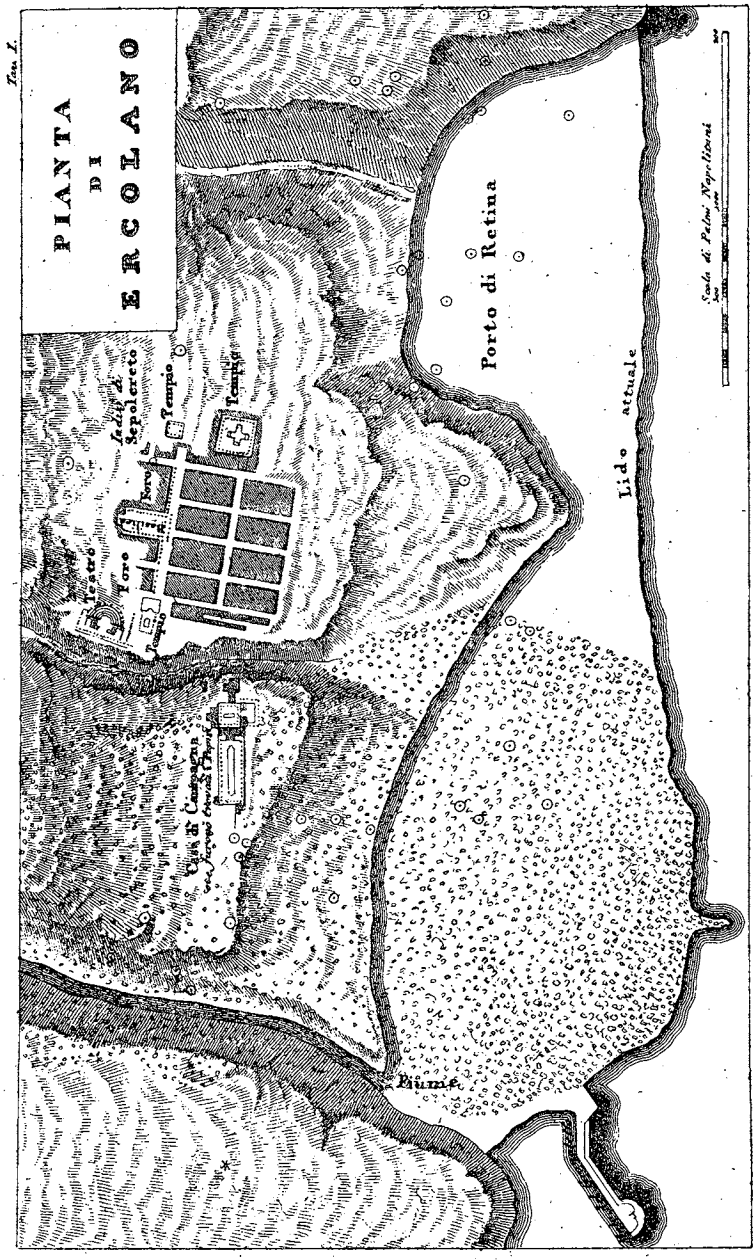
Sir William Hamilton[2] says that near his villa, which was close to the sea, at the foot of Vesuvius, the lava was found 25 feet below the surface, and everywhere we learn that towns and villages stood on the ends of lava flows which frilled the edge of this the "Riviera" of southern Italy.

Herculaneum stood on one of these ancient ridges west of the summit of Vesuvius with a bay or creek on either side (see plan p. 38)[3] into each of which ran a stream fed by springs from Vesuvius and small tributaries from the lower ground, besides receiving the drainage of the town which, in the case of the Romans who always laid on a copious supply of water, was an appreciable addition. On the north-west a larger stream cut off another promontory similar to that on which the town stood. These rivulets ate their way back into the higher ground behind, so that the sea front was divided by small ravines into blocks and bluffs which affected the distribution of the buildings and determined the direction taken by the

[1] *Pompeiana: The Topography, Edifices and Ornaments of Pompeii* 1817—1819.

[2] *Observations, &c.*, p. 48.

[3] After di Jorio, who borrowed from previous writers.


Tav. I.
PIANTA
DI
ERCOLANO
Tesoro
Foro
Tempio
Sepolcreto
Tempio
Porto di Retina
Lido attuale
Fiume
Scala di Palmi Napolitani

ash-laden torrents which finally overwhelmed all the lower parts of the town. These bays, with the harbour, whether of Retina or of Herculaneum, have been nearly obliterated by eruptions of later date than 79 A.D. and greatly modified by the lava of 1631.

Celani writing in 1649 says that before 1631 there was a most fertile plain between Vesuvius and the sea. He cannot have meant exactly what we should understand by a plain, *i.e.* ground approximately horizontal, because there must always have been a slope from Vesuvius to the sea. He probably meant only ground not interrupted by rocks, ravines or any sudden inequalities, *i.e.* a smooth surface though highly inclined. The lava would not have travelled as it did along it, had there not been a considerable slope.

It is clear that there was a valley running along the north-west side of the town, and that still a little further north-west another valley, with a stream in it, ran down to the sea on the south-west side of what is now the Molo di Granatello. Between that and the valley in which the theatre stood was another promontory on which probably many of the villas of the more wealthy inhabitants were built. Here in the garden of the monastery of S. Agostino degli Scalzi, some of the most important excavations were made. On this site the Casa di Campagna stood in which the celebrated papyri were found.

We have also direct evidence that there was a pretty sharp slope from the north-west side of the town down to the level of the floor of the theatre, for there was something in the geographical features of the site which prevented the general symmetry of arrangement being carried out in respect of the theatre. The street and most of the buildings were carried in a straight line from the Forum towards the sea, but this, if continued, would have made the line of the street abut against the side of the theatre and, to avoid this, the street was bent so as to bring the colonnade of the theatre on the line of the street.

Winckelmann, Venuti, and after them many other writers, copying from one another, say that the seats in the theatre looked out to sea; but this, as pointed out by di Jorio, is a

mistake which probably arose from the idea that it was not likely that, in a city so symmetrically built as this, the theatre should not be in line with the other buildings which, up to this point, are perfectly in line with one another.

It would appear, therefore, that those who built the theatre, being unwilling that it should stand with its corner to the Forum and having an eye to other great conveniences and advantages, gave up the strict rectangular arrangement, and by a slight divergence from the straight line of the street and a modification of the approaches to the theatre obtained an access from the high ground to the upper benches and placed the stage on the low ground in the "vallone."

This arrangement was similar to that which was carried out as far as possible in Pompeii, where the theatre was built against a hillside facing south, and also at Misenum and at Cumae, where the seats were ranged along the rising ground and the stage was down in a hollow.

But the point upon which I wish to lay stress is the inference that there was a valley running seawards immediately to the north-west of the principal public buildings of Herculaneum.

Along the sea-front of these spurs the town of Herculaneum and its suburbs extended.

It was described by Sisenna[1] in the 1st century B.C. as a small walled town perched upon a little hill between two streams which ran down from Vesuvius; "oppidum, tumulo excelso in loco prope mare, parvis moenibus, inter duas fluvias intra Vesuvium collocatas" and further as "tutum omni tempore portum habens"; it had a harbour which was safe in any weather. One of the streams is referred to again by the same writer, "transgressus fluviam quae secundum Herculaneum ad mare pertinebat." We owe these quotations not to any interest shewn in the site of Herculaneum, but to a discussion of the use of *fluvia* for *fluvius*.

We must remember that the coast was not exactly what we see there now, for a branch of the lava of A.D. 1631 flowed

[1] Sisenna (B.C. 119—67), *Historia*, lib. VIII, cited by Nonius Marcellus (beginning of 4th century).

in a broad band to the sea, where it made the little spur known as the Granatello. This, therefore, was not there previous to A.D. 1631, and can have formed no part of the harbour which Pliny tried to get into with a view to bringing help to Retina.

Those who pushed their excavations from the public buildings into the town noticed that the houses, as far as they had opportunities of observing them, were very small. It was probably inferior to Pompeii in extent, population and trade. It was like some of those small towns or fishing villages around our coast which have been picked out by the well-to-do inhabitants of the crowded centres of life as beautiful, salubrious, accessible, and in various ways desirable as a temporary residence for those who would seek the sea when the heat and dust of the crowded street became insupportable, or the cold of the more northern or higher regions made those who could afford it fly to the sunny south. These people built then, as they build now, villa residences on every favourable site along the coast on either side of the town, and crept up the hillsides above the original little harbour, around which the primaeval inhabitants had snugly dwelt. The town grew to supply the wants of the wealthy, cultivated population that had gathered round it. We could give many examples of the development of watering places in that way, and this seems to have been the story of Herculaneum.

Venuti speaks of it as extending for a mile and a half along the sea front but he must include the suburbs and adjoining coast over which the villas extended, especially on the north-west of the town, towards where the Royal Villa near Portici was built in later times.

There is plenty of evidence that there were such villas near Herculaneum.

Servilia, the sister of Cato of Utica, had a villa here, and Seneca[1] says that C. Caesar pulled down a most beautiful villa in the neighbourhood of Herculaneum because his mother had been at one time kept there under restraint. He adds that Caesar failed to wipe out its memory by this means because, while it stood, people sailed by without special remark, but now

[1] *De Ira*, lib. III. cap. 23.

everybody asked why it was pulled down. We learn from this also that the villa was near the sea.

We should infer that there was a conspicuous town here, from Ovid[1] mentioning that Aeneas passed it on his return from Sicily.

Pliny distinctly states that there were many pleasant villages along the shore besides Retina and, when the cloud of steam and ash rising from the volcano glowed with the light reflected from the molten mass in the crater until it looked like flame, he said in order to calm the terrified bystanders that it was only the reflection of the flames of burning villages from which the inhabitants had fled. From this two points are clear: (1) that the glow in the sky was such as might be produced by burning villages not directly visible, and (2) that it was a matter of common knowledge that there were such villages along the slopes of Vesuvius, which of course must have been overwhelmed by the same catastrophe.

The Earthquakes of A.D. 63 and 64.

Most of those who have attempted to discuss the destruction of the Vesuvian cities of Herculaneum, Pompeii and Stabiae have treated the subject as if the story commenced with the great eruption of A.D. 79, and have based their descriptions upon the celebrated letter of Pliny the Younger, who simply told us what happened at that time, and what he himself saw or heard from eye witnesses. He was not concerned with the earlier history of the places referred to or with any catastrophes which may have previously befallen the cities which were then overwhelmed by ashes.

For our present enquiry it is clear that we must see what can be made out respecting the earthquakes which preceded the great volcanic outburst of A.D. 79, and what effect they produced in the cities which were a few years later buried in the products of a violent eruption.

It would have been remarkable if there had not been great earthquakes before the sudden renewal of the activity of

[1] *Metam.* xv. v. 711.

Vesuvius after a long period of quiescence, and we find plenty of evidence that there were such earthquakes in A.D. 63 and 64, and that they did a great deal of damage to the cities on the Bay of Naples, and moreover we see in Herculaneum and Pompeii that restoration had been going on apace, but that the effects of the great earthquakes were still obvious when they were overwhelmed in the eruption of A.D. 79. In our attempt to make out, from the condition of the objects found in Herculaneum or in Pompeii, what was the exact character of the catastrophe to which we should refer each disastrous effect, we have this great difficulty to meet. We know that there was a terrible earthquake phase which commenced sixteen years before the cities were buried in ashes, and it is more distinctly on record that the great volcanic outburst of A.D. 79 was accompanied by violent shocks and tremors such as generally accompany explosions. We know also from observations during recent eruptions that the weight of cinders and dust accumulating on the roofs of buildings crush them down, burying everything in ruins and ash, and further that debacles of water and mud rush down the streets and hollow ways and carry all before them. To all these various agencies different writers have attached more or less special importance, but I do not think that in the generalizations which have been offered there has always been a sufficiently careful discrimination between them.

In an enquiry into the history of such complex phenomena as those which confront us in the excavations of Herculaneum, it will be well to consider the usual course and relation of earthquake and volcanic phenomena, and to distinguish the earthquakes accompanying the great earth movements which make volcanoes possible, but which may or may not be followed by eruption, from the smaller earthquakes which are merely shocks and tremors produced by explosions at or near the surface. For there are two kinds of earthquake; the tectonic and the volcanic.

Tectonic earthquakes are those which are caused by violent disruptions in the earth's crust, the distribution of the vibrations due to which is determined by the length, depth, inclination

and other conditions of the fissures produced in relief of the folds in the rocky crust.

The cause of these cracks in the crust is primarily the local crumpling of the exterior part of the earth's crust in adjustment to a changing nucleus.

Great effects may be produced by the contraction and expansion of matter as it changes from the molten to the solid or from the amorphous to the crystalline state. Chemical reactions must play a part, and the redressing of stresses and strains, due to astronomical combinations, or to the shifting of masses of matter by denudation or accumulation at the ends of coordinate axes across the rotating teetotum on which we live, by which we may correlate synchronous seismic action at opposite sides of the earth: each of these is a *vera causa*, but, in the main, we have first to take account of the great folds which raise continental areas here and depress ocean basins there round the circuit of the world—and which are hence spoken of as *epeirogenic*. If, interested in this question, we were to go to the Alps and Appalachians and calculate, on the basis of what we see there, how much greater the circumference of the earth would be if we could iron out all their sigmoidal flexures, we should be obliged to acknowledge that it cannot have been so large within the periods with which we are dealing, even allowing for the molecular rearrangement that compensates by vertical thickness for tangential compression. So, extending our observation, we learn that, while the great folds are of universal extent, the sharp plications occur along very limited crumple-belts. If the earth's crust were perfectly homogeneous, and all under similar conditions, the gentle folding might effect all the readjustments necessary; but the crust is made up of very variable material, subjected to different conditions, and gives way most along lines of weakness and greater stress, and those crumple-belts are produced of which we see the results chiefly in mountain chains, and so we call these movements *orogenic*.

Every rock has its pressure and its time, and if a rock is bent too fast it will break. In these more violently twisted rocks great rents occur, often with relative displacements on

either side, and, in the readjustments, smaller cracks are produced, and we feel vibrations of greater or less intensity and call them all earthquakes. Those which have to do with the structure and manner of building up the earth's crust we call *tectonic earthquakes.* The class of earthquakes due to the violent explosions which take place during an eruption are spoken of as *volcanic earthquakes,* and will be described hereafter. They are mentioned by every one in connection with Vesuvius from Pliny referring to the eruption of A.D. 79, to the newspaper writers who described the outburst of this year 1906. As the great folding is always going on, these rents recur at various intervals with intervening periods of quiescence lasting till the rocks have to yield again.

The terribly destructive effects of recent earthquakes, which have devastated some of the most important and populous centres of civilization and commerce, have given an impulse to the scientific examination of earthquake phenomena.

After the great earthquake which nearly destroyed San Francisco on April 18, 1906, a commission was appointed to investigate and report upon its causes and the observed effects. It was severe over an area extending about 400 miles in length by 50 in breadth, while smaller vibrations were felt much further. The commissioners in their report expressed the opinion that the cause of these movements in general terms is that stresses are generated in the earth's crust which accumulate till they exceed the strength of the rocks composing the crust, and they find a relief in a sudden rupture. This establishes the plane of dislocation in the first instance, and, in future movements, the stresses have only to accumulate to the point of overcoming the friction on that plane and any cementation that may have been effected in the intervals between movements. With regard to the effects upon the rock on either side of the fissure or fault thus produced, the Report goes on to say: that there was a differential vertical movement not exceeding 4 feet, and a horizontal relative displacement on a nearly vertical plane to the extent of from 6 to 20 feet. It was inferred that the great length of the rift implied a great depth of rupture.

It was shewn further that there was a maximum of destructive effects immediately on the rift line, but that there were other lines of great, though varying, intensity along the floors of the adjoining valley systems, and it was pointed out that these regions "are underlain by loose or but slightly coherent geological formations, and their position strongly suggests that the earth waves, as propagated by such formations, are much more destructive than the waves which are propagated by the firmer and highly elastic rocks of the adjoining hill lands. This suggestion is supported by a consideration of the destructive effects exhibited by towns and single buildings along the same valley line which are situated wholly or partly on rock[1]." This point, however, requires further elucidation.

Whatever may be the system of folding of which this is a subordinate branch, it is clear that the axis of the particular earth movement which we are considering, was from Vesuvius to Ischia, and therefore Misenum was within the area where the tectonic earthquakes would be chiefly felt. This explains the recession of the sea and the terror of the inhabitants, for we must remember that they had left their houses, and were out on the road into the open country near the sea before the dark cloud of ash described by Pliny the Younger fell.

During the long period of quiescence of Vesuvius the lavas cooled and hardened, and the volcanic necks were choked, but the whole area was on a crumple-belt and in the course of movement and folding the crust gave away again along the old lines of fissure, and a great series of vibrations were caused —that is to say, a renewal of what we have defined above as tectonic earthquakes. No molten matter reached the surface for sixteen years, but it kept eating its way up and assimilating the rocks through which the fissures passed.

Seneca[2] records that part of Herculaneum was ruined by an earthquake during the consulship of Memmius Regulus and Virginius Rufus, that was in A.D. 63, and it was probably an

[1] "Report S. Francisco Earthquake Investigation Commission," David, Prof. T. W. E., *Sydney Daily Telegraph*, Dec. 1906. Upham, Warren, *Journ. Trans. Vict. Inst.* Vol. XXXIX. 1907. Irving, Rev. A., *Nature*, May 1905, Vol. LXXII. pp. 8 and 79.

[2] *Quaest. Nat.* lib. VI, cap. 1 and 27.

earthquake that in the following year A.D. 64 in the consulship of C. Laecanius and M. Licinius destroyed the theatre in which Nero had just been performing[1].

These were tectonic earthquakes, and there is no mention of any volcanic outburst.

It seems certain that the theatre of Herculaneum was destroyed in some of these earthquakes, and was rebuilt or being restored by Titus when overwhelmed by the eruption of A.D. 79.

Venuti points out (p. 70) that if the spectators perished with the theatre in A.D. 79, as, he says, is stated by Ziphilinus, recent excavations should have exposed traces of their bodies and bones, but nothing of the kind was found. But if he refers to a destruction of the theatre by an earthquake in A.D. 63 or 64, there was plenty of time to clear it out and remove the dead bodies before A.D. 79. If he refers to the eruption, the people would have hurried home from the theatre when the ash began to fall thickly.

Moreover the gilt Colossus and inscription to Titus, if the accounts handed down respecting them can be trusted at all, cannot have been placed there after the eruption of A.D. 79 but must refer to his restoration of the theatre after it had been destroyed by the earthquakes which commenced in A.D. 63. There is often some confusion between destructions and restorations of Herculaneum, Naples and Pompeii.

Titus further ordered that the goods of those who died without heirs should go to the rebuilding of the city, and the loss of so many citizens was made up by the addition of *liberti* under the name *adlecti* or *adjuncti*. "Titus rebuilt and adorned this theatre, as he had done several public buildings which had been thrown down by earthquakes in other parts of the world."

What end is there, Venuti asks, to strain so hard to prove this statue of Titus erected for the repair of the theatre after the total destruction of the city, the 24th August, A.D. 79? Is it not more probable that it was erected for the repair of the damage occasioned by the earthquake of A.D. 63, mentioned by Seneca?

The results of excavations tell the same story, for drums of

[1] *Ann.* lib. xv. cap. 33, 34. Suetonius, *de vit. Caes. Nero.* 20.

columns and pieces of statuary were found broken and scattered in a manner that could be explained by their having been thrown down by an earthquake and left lying here and there over the surface, but is inconsistent with the view that they were crushed down with the buildings falling under the weight of cinders or washed down with the rainwash of volcanic ash, unless they had been lying about in fragments.

Venuti (p. 99) records that "besides the Temple of Hercules there were other temples as of Apollo, &c., of which deity there were found two large statues without heads." These may have been broken off by the fall of the roof under the weight of ashes, but in that case the heads should be found close by.

Venuti says also that on the sides of the Basilica there "were fixed pedestals, with statues of brass which had been partly melted by Vesuvius." As is explained elsewhere, there is no ground for inferring that there was any "nuée ardente," or lava, or fall of ash, sufficiently hot to have affected bronze statues, but everything points to there having been torrential rains washing the ash down the slopes into the hollows. If the objects found in any buildings shew signs of fire we must rather suppose that, as was the case recently at San Francisco, they were in buildings ignited by being thrown down upon the fires and combustibles contained in them; and, though this may have been caused by the weight of cinders on the roof, it is to be referred with greater probability to some earthquake shock previous to the eruption. In the neighbouring city of Pompeii, where excavations have been carried on with much greater care and to a much greater extent than in Herculaneum, the evidence of destruction due to earthquakes is clear. Moreover we see there that it was not only the minor earthquakes which accompanied the eruption of A.D. 79 which shook down buildings which were being buried under ash, but that there had been a great catastrophe some years before from which the city was only just recovering, for we find signs of rebuilding and repairs everywhere, and often the fragments of ornament and sculpture belonging to buildings which had never been restored, and these must have been left lying about, so that only portions now remained, and portions of such a kind and

size that it is obvious that the ruins must have been exposed and the missing parts carried away for use elsewhere. If they had been broken up during the eruption of A.D. 79, the whole would have been covered up and all the pieces found in the course of excavations.

One of the most difficult to explain fully is an inscription on a brass plate said to have been found fixed to a wall in Herculaneum, which contains an order that no ancient buildings should be pulled down for the sake of selling the materials.

Now we must infer that there were some ancient public buildings which had become dilapidated and were being destroyed for the sake of the materials, as were our castles and monastic buildings. But are we to suppose that these belonged to a much more ancient city, or that some of them were ruined by earthquakes which became frequent and intense just before the great eruption which overwhelmed Herculaneum and Pompeii?

There are distinct traces of earthquakes having occurred either some time before or at the commencement of the eruption which overwhelmed the city, for the drums of columns are buried in the ash. They must therefore have been thrown down before the ash fell, but of course this may have been done either in the earthquake of A.D. 63 or in those which occurred, as Pliny records, at the commencement of the eruption of A.D. 79. We see that the temples of Jupiter and Mercury and Venus had been quite recently restored, while the Forum and the Chalcidicum were unfinished when the eruption of A.D. 79 overwhelmed them.

It would seem however that the early excavations were not very carefully or judiciously carried on, for Venuti says (p. xii), "And as the Diggers broke and destroyed every Thing, so this Architrave, though whole in the Ground, was shattered to Pieces, so that perhaps different Things were put together, and by that means every Thing confused," to which his commentator adds in a footnote, "And what else could be expected; since this most magnanimous King permits this unestimable mine to be dug by Galley slaves chained two and two: and it is a general complaint among Travellers

in their Letters hither concerning this Place, that all those called Superintendants are totally ignorant of what they are about; Nay, our author makes almost the same complaint in several Places." Venuti goes on to say, "It was indeed proposed, that every Thing should be preserved; but that could not be obtained; only the more precious Things are preserved, and placed as ornaments in the Royal Villa of Portici; in which the following inscription is put up, which I proposed, and which for its Plainness I take great Pleasure in."

See also ironical comparison of the work of Charles to the destruction of a villa near Herculaneum by Caesar, pp. xiv, xv.

In his excellent handbook to Pompeii[1], Mr Neville Rolfe, our Consul General at Naples, points out numerous examples of what he considers evidence of earthquake action earlier than A.D. 79. For instance, he infers on p. 75 that the statues in the market place, the character of which is known from a painting in the Naples Museum, many of which were equestrian and most of which were in bronze, were thrown down in the earthquakes of A.D. 63. They had not been replaced, and the restoration of the pillars, which was in the newer Ionic style, was not finished when everything was overwhelmed in the eruption of A.D. 79. No trace of any statue was found in connection with the triumphal arch dedicated to Nero Caesar. If it was thrown down in A.D. 63, it, or the broken pieces of it, would have been removed before the eruption of A.D. 79. The decoration of the roof of the room called the Apodyterium in the forum baths was repaired in such a way as to suggest that it had been damaged some years before, and niches were bricked up apparently to strengthen a shattered roof. The roof of the smaller or Comic Theatre had been destroyed probably by the earthquake of A.D. 63 and new tiles placed ready for use by the workmen, shewing that it was being rebuilt or repaired when the outburst of A.D. 79 overtook them.

The marble slab of the table in the Atrium of Cornelius Rufus was missing altogether, and as such a thing could not have been carried away after it had been buried in the ashes

[1] *Pompeii, Popular and Practical*, by Eustace Neville Rolfe, Naples.

of A.D. 79, we must suppose that it was broken in the earthquakes of A.D. 63 *et seq.* and had not yet been replaced.

The House of the Tanners near the Stabian gate "shews signs of having suffered considerable damage in the A.D. 63 earthquake, as the pillars of the Atrium were rebuilt in the latest Pompeian style, though the remains of the more ancient tufa pillars are still visible."

There is plenty of evidence of the great destruction caused by earthquakes previous to A.D. 79, besides the broken statuary and buildings in ruin or being restored. For instance, a bas-relief on the lararium in the house of Caecilius Iucundus represents a temple being destroyed by an earthquake, and an inscription found in the course of excavations in the temple of Isis records that "Numerius Popidius Celsinus, the son of Numerius, restored from its foundations and at his own cost the house of Isis which had fallen down in an earthquake."

On the other hand we must remember that very few ceilings have been found in Pompeii. Now, as we know that the city was restored and inhabited after the earthquake of A.D. 63, we must admit that most of them were broken down by the weight of ashes and perhaps by some of the shocks during the eruption of A.D. 79. Of the temple of Hercules, which is the most ancient and the most massive, and which was for centuries the most magnificent building in the city, there is but little left. Nothing is known as to how or when it was destroyed, and what was done with the massive stones of which it was built is a matter of speculation, as they would not be so much in request after A.D. 63, when most of the restoration was in brick, not stone. Cases of this kind where the explanations are conjectural must occur, it is a wonder that there are not more.

If the inscription recorded in Venuti[1] is earlier than the destruction of Herculaneum it shews that there was a poor population there glad to receive charity from their wealthier neighbours. But the age of the inscription is questioned and perhaps, as suggested by Venuti, it belongs to a colony from Herculaneum which occupied a part of Naples, or it may shew

[1] p. 34.

that the whole of Herculaneum was not destroyed even by the eruption of 79.

But one of the most important of the questions requiring further elucidation is here suggested—How and to what extent was either Herculaneum or Pompeii reoccupied or explored immediately after the catastrophes of the 1st century?

The damage done by the earthquakes of A.D. 63, 64, must have been great; perhaps shocks of greater or less intensity recurred for many years, and it may be that the inhabitants of the ruined cities and their patrons did not begin the work of restoration for some time after the first great shock of A.D. 63 because they did not feel sure that the period of seismic activity was past. However that may be, we find plenty of evidence in Herculaneum of the ruin caused by them, and still more clearly at Pompeii, where the area uncovered is so much greater and observations have been so much more carefully made. Though the lower parts at any rate of the walls of Pompeii, and to a greater extent those of Herculaneum, were too deeply buried to be carried away whenever building material was wanted for local purposes, still we must allow the probability that many of the inhabitants who had left money or jewels, or other objects of considerable value when the great shower of ash began to fall, expected that, if they escaped the immediate effects themselves, they could easily return and sweep away the dust and reoccupy their houses.

When, however, they found the roofs crushed in and all buried to such a depth that they must seek a home elsewhere they would still certainly try to recover some of their possessions: and, if the owners did not, a whole class of treasure seekers would spring up who would tunnel from house to house and room to room.

The Eruption of A.D. 79.

After the earthquakes the survivors quickly returned to the flanks of Vesuvius in forgetfulness of the past and confident hope that no catastrophe would occur again in their time. The extraordinary fertility of the soil and the rapidity with

which the crops are produced encouraged them to be early in the field. I was told that the purchase value of the vineyard adjoining the excavations at Herculaneum would be about 1500 lire per 100 square metres, that is about £750 an acre, while the land on the upper slopes fetches a rent of £8 an acre.

As Egypt is said to be the gift of the Nile, so the happy lands of Campania Felix, and the rich flanks of Vesuvius, may be called the gift of the mountain, and, as no danger from flood ever kept man from the one, so no fear of the internal fires has ever restrained him from returning to the sunny slopes of the other.

The towns also which had been desolated by earthquake were soon restored and repeopled, and the busy life went on as before. The traces of catastrophe were not perhaps all cleared away for many years, for men soon regard the ruin and the broken column as familiar objects, and, unless they obstruct the way or are wanted as material, they are let lie where they fell.

The relation of earthquakes to volcanoes is very complex in detail, but it is not so difficult to formulate a general sketch which will at any rate suggest a *vera causa* of great potency.

The increase of temperature as we descend into the crust of the earth is *à priori* probable, and, as far as direct evidence can be obtained from borings, &c., is a fact. The increment has been variously estimated at about 1° Fahr. for every 50 feet to 60 feet depth. There is considerable local variation, and some observations have been recorded in which the rate is much lower, and some much higher. But for our present purpose what I have mentioned above gives a fair average. It is clear therefore that we soon reach a temperature at which all known rocks would be fused. The temperature of flowing lava has been shewn by the experiments of Scacchi and Sainte Claire Deville to range from 1228° F. to 2204° F. These temperatures would, if there were no disturbing element to be taken account of, imply a depth of from 15 to 20 miles. The experiments[1] of Hopkins, Fairbairn, and Harcourt have however shewn that the promotion and maintenance of the solidification of mineral

[1] *Brit. Assoc. Rept.* 1847, p. 47.

matter is affected by the pressure, from which it follows that, although a rock may be at the temperature of fusion, it may be prevented by pressure from becoming molten.

We have seen above that tectonic earthquakes are due to folds and cracks and movements, the result of which must be to relieve the pressure and release the superheated rock, which, on assuming the molten state, escapes up the fissures, melting and assimilating the rocks through which it passes till it gets near the surface and its gases begin to expand and be released under the diminished pressure; while the molten rock in most cases comes in contact with surface waters, which, being suddenly converted into steam, produce all the phenomena of an eruption.

The explosive stage is not a necessary part of every volcanic development. In the Hawaiian islands earthquakes occur, and huge waves roll in, which tell of movements out at sea. But the lava stands boiling in one vast crater 4400 feet above sea level, with vertical walls 1000 feet deep which shew by their unbroken rim that they have not been subjected to destructive explosions like those of Vesuvius. There is every now and then an overflow of lava which runs for 40 or 50 miles or so. Vesuvius in eruption makes more noise and gives off more gas and steam and smoke and ash, though its lava-flows are trifles compared with those of Kilauea. If a sudden fault or fissure were to let the water of the Pacific into the lower regions of the Kilauea crater we might have such an eruption as has seldom if ever been recorded.

The folding of earth's crust gives rise to faults, and, though the vibration is felt far and wide, it may be long before the rock, relieved of pressure and therefore becoming molten, and aided by variously produced pressure when molten, eats its way up and simmers at the surface as in the craters of Hawaii, and only when it has found water near the surface will it develop an explosive eruption. Some authors have suggested that gases, especially chlorhydric acid, chlorhydrate of ammonia, and carbonic acid gas, play a more important part in producing explosions than has generally been supposed. Indeed M. Albert Brun of Geneva assigns the principal effects to them and con-

siders that steam plays quite a secondary part, and that in fact it is rarely present in any large quantity. It is difficult to reconcile this view with the invariable fall of torrential rain from the clouds overhanging the volcano and other coincidences of paroxysms with probable inrushes of water. The evolution of gases when the pressure is removed has always been admitted as an agent, but not as the principal agent in the production of paroxysms.

In the last eruption of Vesuvius (in 1906) it took many months for the lava standing in the crater to assimilate portions of the containing rock, and either eat its way out through lateral vents or undermine the wall of the crater so that huge masses fell into the caldron and produced new and increased explosions. This from the nature of the case could not be a rapid process.

A deep seated crack took place in A.D. 63 and the shock caused by it threw down a great part of the Vesuvian cities. Shock after shock occurred along the shattered belt of rock for sixteen years, until the molten rock, replenished *a tergo* by newly melted matter, made its way up, thrusting, assimilating and raising the temperature of all the rock through which it rose, until at length it met with a body of water, either the fresh water that had collected in all the upper strata, or water of the sea that had been suddenly admitted through the broken crust into the seething caldron of molten rock, and the violent explosions due to steam immediately followed. These explosions also independently caused shocks and tremors, "volcanic earthquakes," which simulated and very likely gave rise to a repetition of the deep seated "tectonic earthquakes."

We have numerous examples of the results of explosions at or near the surface of the earth, and the effects are analogous to those observed in the case of this superficial paroxysmal action of volcanoes. Accidental and criminal explosions of dynamite or the bursting of a steam boiler teach us that the shocks and tremors, due to such superficial or shallow agencies, are quite analogous to the shocks felt in the later stages of a volcanic eruption. The shocks are felt through the air and in the earth. How much greater must be the effect of the sudden

expansion into steam of such immense bodies of water as we have to take account of in the eruptions of Vesuvius. It has been estimated from the average size of the cloud observed for a long period hanging over Vesuvius that it represented about 20,000 cubic yards of water, and this cloud was being continually dissipated and continually renewed by the uprush of steam from the crater, while Fouqué estimated the water discharged by Etna during an eruption at about 30,000 cubic yards a day. This gives one some idea of the quantity of water that must be supplied from somewhere to the vast boiler in which it is converted into steam, and if it is admitted sometimes more regularly, sometimes intermittently, we see the result in the recurring outbursts. Not only so, but the water is derived from various sources; there is the water in combination, there is the surface percolating water, there is the sudden inrush from river, lake, or sea, as earthquakes form new fissures or reopen old ones. It gains access to the molten matter now higher up now lower down, so that sometimes it is simply boiled and rises in vapour, sometimes it lifts off the lid of the great caldron, sometimes it blows out the heated water, and sometimes the melted rock. There is no regularity in the recurrence of volcanic outbursts nor in the intervals between the paroxysms during an eruption, but experience has produced a general expectation that there will be a period of rest after a display of activity and that it will be of longer duration after a violent outburst, and from the analogy of geysers this is probable.

Nor can any estimate be offered of the time likely to elapse between the first deep-seated tectonic earthquake and the volcanic outburst at the surface.

Earthquakes were felt all through the period of eruption in A.D. 79, and it is probable that some of these were accompanied by earth movements which caused a recession and advance of the sea, perhaps several times, but that was not what caused the shallowing of the water when Pliny first tried to reach the shore. They may have occurred at Misenum and probably did account for the troubled and tempestuous sea off Stabiae. We must not attach too much importance to the dead fish on the

shore; they were probably killed by the excess of ash and mud in the water and thrown by the wind waves on the beach.

We have no exact record of what was going on in the crater from A.D. 63 to A.D. 79. It is probable that what happened then was, only on a much larger scale, what happened during the recent eruption of 1906. The lava had been long simmering at the bottom of the great caldron, and had been assimilating the old material of the cone, and eating its way in sideways along lines of weakness, and sometimes even finding its way out through openings in the side of the mountain. Such was the lava flow which was seen from Naples in the early part of 1906. As I then pointed out to my companions in Naples, it was quite clear that Vesuvius could not have gone on long as it was, for either the accession of molten matter must cease, or it must eat its way sooner or later into or through the tapering cone. At last the critical moment came and a vast undermined mass fell in, and, like the sods in the geyser, precipitated an explosion of greater intensity and blew off a great portion of the newer crater leaving the Monte Somma as the highest peak. But it was sixteen years after the first recorded earthquake of A.D. 63 that, in the reign of Titus, the great eruption occurred which destroyed so many towns and villas on the lower slopes of Vesuvius. Three important cities, Herculaneum, Pompeii, and Stabiae, are known to have been overwhelmed, but how many smaller places and detached residences were buried is now only a matter of conjecture and inference, and in the consternation with which the news of such a catastrophe, occurring in the great centres of population, was received, the fate of many a smaller town or village may have escaped record.

If this be so, what we have to deal with, in the case of both Pompeii and Herculaneum, is a city which was roughly shaken by the great earthquakes of A.D. 63 and 64, and perhaps some later shocks, and which was being rebuilt between that and A.D. 79.

This explains how part of the city was still occupied by the poorer classes, why there is some difficulty in reconciling the statement, that the catastrophe occurred when the people were in the theatre, and yet we find no bodies buried there, why we

have an inscription mentioning that the theatre was rebuilt, why there were proclamations forbidding the inhabitants to remove the remains of ancient monuments. We have two great catastrophes to take account of, first a succession of earthquakes from A.D. 63 on, and secondly the eruption of A.D. 79.

The larger general questions with which we are now dealing cannot be altogether separated from those details as to the month, day, and even hour at which the eruption took place, because, for instance, we have to account for the darkness, and it would make a great difference whether the eruption took place as night was coming on. We have to explain the absence of bodies in places where we should expect to find them if the cities had been overtaken in the night, or when the inhabitants were in the theatres, or other places of public resort, and ingenious inferences as to the season of the year have been drawn from the raisins, walnuts, &c., found in Pompeii. But these questions only arise incidentally in connection with the points which now are under consideration.

In the case of geysers we have on a small scale a similar action to what, *mutatis mutandis*, is seen in volcanoes. We have in both a period of quiescence till the expansive force of steam or other gases can overcome the superincumbent weight of water or of lava. In both we have the column of steam invisible at first, but condensed as it reaches a colder region. In both we have the tremors, the rush, and the roar of the ascending liberated matter.

It is of course of great importance for our present enquiry to ascertain what part heat and fire, hot ashes and hot blasts, may have played in the destruction of the towns and villas we propose to explore.

I quote here such parts only of the story of the great eruption as bear upon the geological questions under consideration. First we learn that when the attention of Pliny the Elder had been called to the remarkable appearance of Vesuvius, he ordered a fast sailing cutter to take him to see what was going on, but just as he was starting he received despatches, from which he learned that matters were so serious that he changed his plans and ordered the fleet to be got under way

and with it he sailed with the intention of bringing help to the towns and villages on that thickly populated coast. One would like to know how these despatches were conveyed. If they were brought by land round by Naples and Baiae that must have taken a long time; and if they were brought by sea across the bay it must have been in a rowing boat as the wind was adverse. One cannot help wondering why the harbour of Herculaneum, which, as we have seen, was reputed to be safe in any weather, was not mentioned. Did Pliny think that Retina, the modern Resina, was in greater danger being nearer the crater, or was Retina more in the district covered by villas among which Pliny must have had many friends. Some authorities accept a reading which makes Retina or Rectina a person not a place, in which case no towns are mentioned by Pliny.

We learn that there was an upper current of wind blowing from the crater by which the lighter material was carried over Misenum, but down below there was a wind blowing in the other direction, which enabled Pliny to sail to the coast near Vesuvius and afterwards on to Stabiae, where Pomponianus could not get out because of the adverse wind, and where Pliny stayed and died.

In the recent eruptions in the West Indies we have it recorded that on one occasion the ash was carried over the city by a wind blowing not from the crater but from the opposite direction.

The light ash dropped at last from the upper current into the lower, and after Pliny the Elder had left with the fleet, it was seen by Pliny the Younger and his mother coming along after them with the wind, like a thunderstorm drifting across the country in summer. When it overtook them they were in total darkness. This is all natural enough. Anyone who has stood near a large bonfire knows how the lower air rushes in towards it while the sparks are drifting in the upper air in quite different directions.

This wind was favourable for Pliny the Elder and he sailed away with his fleet to the nearest part of the coast, to the source of danger, namely Vesuvius.

After the Elder Pliny and his fleet had sailed away, and,

owing to the threatening appearance of the sky, the Younger Pliny and his mother were escaping together from their house at Misenum, he says that he looked behind him, and saw a dense cloud following them and spreading over the country. He suggested to his mother that they had better turn aside off the road while they could still see for fear that if they fell on the road when the darkness overtook them, they might be trampled under foot by the crowds of people who had joined them in their flight. They had only time to get off the track and sit down when darkness overtook them, not such as they were familiar with when there was no moon or when there were heavy clouds, but such darkness as there is in a closed room when the lights have been put out.

This was due to a cloud of ash which soon overtook them, but it is not said to have been hot.

As Pliny the Elder approached the coast he found that the ash fell more thickly and the fragments of lava which dropped on the ships were larger and hotter: of course because the heavier particles which fell nearer the source of eruption had not travelled far enough or through sufficiently cold air to have their temperature so much reduced as the ash that had been transported far through the higher regions of the atmosphere.

In order to understand Pliny's description we must clearly distinguish between the hot ashes that fell on his ships and the blast of hot air and hot ash that composed the "nuée ardente" so graphically described by Lacroix as the most terrible feature of the great eruption of Martinique. This was hot ash and superheated steam and gas and splutterings of lava driven out horizontally and downwards instead of vertically through the main crater. It was as though the mouth of the great cannon which usually carried fragments of rock thousands of feet straight up into the air were turned down and it were fired point blank at the doomed city, so close that it was not only raked by the shot but also scorched by the fire of the explosion.

"It is necessary finally to consider a variety of the Vulcanian type, which I will call Peléean. It differs essentially in that the proportion of solid materials carried away by the cloud is much greater, so that instead of ascending vertically, as in the

preceding case, it descends upon the flank of the volcano and flows or rolls upon the surface of the ground with accelerated velocity. Sometimes as in the eruption of St Vincent (1902) and the small eruptions of Mont Pelée, its motion is essentially the result of gravity alone; at other times, as in the great paroxysms of Mont Pelée, the cloud has been directed by an initial thrust and by gravity working in the same direction. A Peléean cloud is also animated by an ascensional movement due to the expansion of water vapour, but this is of secondary origin and its direction is not the same as that of the initial thrust. The cloud ascends vertically as it rolls downward upon the surface of the slope.

I employ the term Peléean cloud as more general than that of burning cloud (nuée ardente) because similar clouds are conceivable at temperatures inferior to that characterizing the eruptions of the Antilles, although the high temperature undoubtedly plays an important part in the mechanism of the cloud and in the stability of the emulsion of solid material in the water vapour that characterizes it[1]."

"Une nuée ardente était le résultat d'une violente explosion, qui brisait la carapace solidifiée du dôme de lave récente, entraînait sur les pentes de la montagne et pendant de nombreux kilomètres, une sorte d'émulsion, à haute température, de fines poussières dans de la vapeur d'eau et des gaz divers, charriant en outre des fragments et des blocs de lave, aux proportions colossales. Lors des grandes éruptions, la nuée était dirigée à la fois par la projection initiale et par la pesanteur, s'exerçant dans le même sens; dans les éruptions de moindre importance, cette dernière force seule jouait le rôle directeur, une fois la nuée en marche[2]." He explains that a dome of acidic lava was built up in the crater of Mont Pelée and that from the sides of this dome there were intermittent explosions of matter which looked as if it were compact and almost solid and rolled down the steepest descent with a velocity

[1] "Eruption of Vesuvius in 1906," *Rept. Smithsonian Inst.* p. 225.

[2] "Pompeii Saint-Pierre Ottajano," *Revue Scientifique*, Oct. 20, 27, Nov. 3, 1906.

of sometimes 50 metres a second and from which rose a cloud of watery vapour, gas, and ash, advancing with it down the slope. He estimated the temperature at little less than that at which lava solidifies, namely about 1100° C. while the large blocks on the margin were still red-hot and the ash had a temperature of more than 200° C.

What is characteristic of this phenomenon is then its brief duration; the narrow belt to which the action was confined; the sharp line of demarcation between the devastated area and that which was untouched; the great velocity and volume and consequently the enormous momentum of the mass; the intense heat; and the extraordinary destruction of life.

Although there is enough to suggest the comparison, nothing exactly like this is recorded in connection with any of the eruptions of Vesuvius.

Dr Tempest Anderson explains the *hot blast* as the current produced by the avalanche of incandescent fragments in the same way as an avalanche of snow causes a displacement of air which frequently does more damage than the avalanche itself. An example of this occurred in 1895 when a mass, estimated at 4,000,000 cubic metres, fell from the Attels glacier near Kandersteg into the valley beneath. The woods, châlets and houses on the opposite side of the valley were all swept away by the rush of air caused by this huge fall.

The avalanche of incandescent fragments descended by gravitation through a gap in the rim of the crater but was urged forward by the giving off of the water of combination from every surface of the comminuted rock. The tremendous velocity of the lava was due to the evolution of gases within the mass and the direction of the hot blast to the drag of this descending current of mixed lava and superheated steam. Whatever may be the true explanation of this phenomenon we have no reason to believe that anything of the sort occurred in connection with the eruptions of Vesuvius. While Lacroix describes the clothes and surface of the bodies found in the path of the blast at Martinique as carbonized and the walls which stood across it as all carried away and only those left standing which ran lengthwise to its course, we learn from

Pliny that his uncle's body was found untouched by flame, and the houses in Herculaneum, except some standing in the line of the mud laden torrent, do not indicate any such belt of destruction.

There were few cases in which the objects were burnt and those, as I have explained, can be best accounted for in another way. There is no trace of a blast carrying everything before it and levelling every wall that crossed its path and leaving only those that ran in the direction of the blast. The only thing that could suggest such an agent was the occurrence of debris of buildings, and fragments of metal and marble, in lines along the course of the ash-laden flood from the torrential rains, which swept everything down the hollows.

Dr Tempest Anderson[1], pp. 194 *et seq.*, adds some important observations which bear directly upon the explanation here given of the material in which Herculaneum lies buried. He describes the effects of the torrential rains—not only of those due to the condensation of vapour issuing from the crater, but also those recurring in the rainy season in that climate. "It is a peculiarity of this volcano (the Soufrière) and Mont Pelée that in the recent, and apparently in several former eruptions, no true lava has been discharged, but an enormous amount of very hot sand and scoria mixed with much superheated steam and sulphurous gas has rushed down the mountain-side in a sort of incandescent avalanche destroying every living thing in its path. The outskirts of this avalanche, where it was mixed with air, constituted the 'Black Cloud' or 'Hot Blast' so frequently mentioned by the press. At the time of our visit, about a month after the first eruption, the rainy season had set in with unusual violence, as much as five inches of rain having been measured in one day, and this enormous amount of water rushing down and meeting with the still hot sand caused explosions of steam and dust on a large scale which at first were supposed to be due to genuine volcanic eruptions."

The Rozean Dry River "is a small stream in the Wallibru

[1] *Volcanic Studies in Many Lands*, Lond. Murray, 1903.

Basin. When the water undermines the banks and the hot ashes fall into the river, as described in the last instance, the stream is often temporarily dammed up, and the giving way of the obstruction is associated with a great discharge of boiling mud. In one of our ascents of the Soufrière we had crossed the Rozean Dry River without difficulty in the morning when the weather was fine, but heavy rain had fallen before our return in the afternoon, and the river was full of boiling mud coming in gushes."

From these descriptions we learn much.—We may well be inspired with caution in our endeavours to interpret the records of phenomena which happened two thousand years ago when we see the difficulty of understanding what has been going on in our own time and respecting which we have had opportunities of conversing with eye witnesses.

We see that some of the most fearful effects of volcanic eruption, the lava flows, may be due not so much to the simple overflow and descent by gravitation of molten matter over the lowest lip or through the first fissure through which it has found its way, but that it may have been urged forward by the all pervading evolution of steam and gas within the incandescent fragmental mass.

We see that this may be accompanied by a fiercely hot blast of steam and gas and air, and we may speculate as to how much of this is due to the initial explosion from a lateral crater and how much to the drag and impulse of a swiftly descending and expanding stream of incandescent molten rock.

We see that torrents of rain water excessive beyond all record under ordinary atmospheric conditions, fall on and with the fiery fragments, and, heated by the steam and ash, pour down the slopes and hollows, hurrying along thick and turbid with mud and cinders, and producing abnormal phenomena of denudation and deposition.

All these things might have been equally violent on Vesuvius and in trying to read the story of Herculaneum we must carefully examine all available evidence to see whether we are dealing with a case in which the conditions differed only in degree or also in kind.

In view of the suggestions which have arisen from the mode of occurrence of the bronze and other statues in Herculaneum it is interesting to read the following description given by Lacroix.

"La nuée avait laissé la trace de son passage enregistrée à travers la ville—en couchant vers le Sud les arbres et le phare—en transportant dans cette même direction tout ce qui était transportable et même une statue de bronze, pesant trois tonnes, trouvée gisant à quinze mètres de son piédestal—en renversant les murs orientés perpendiculairement à cette direction, alors qu'étaient relativement respectés ceux disposés dans le sens de sa trajectoire. Les dimensions connues de quelques-uns des monuments détruits à permis d'estimer à 130 ou 150 mètres, à la seconde, la vitesse probable de la nuée, au moment où elle renversait ces obstacles."

However the broken and scattered statues of Herculaneum and Pompeii may have been transported, it cannot have been by any such scorching blast as that which accompanied the eruption at Martinique and carried instant death and destruction in its path.

Mr Flinders Petrie has forwarded the following note with a view to its being communicated to the Society this evening.

"In view of a systematic excavation I wish to call attention to some points which are perhaps not sufficiently in view.

The great find of bronze figures—the Hermes, Faun, and Satyr—are of most exceptional nature; they are all bronze and no marble was with them; being hollow, they are all lighter than volcanic mud; and they are all unattached to their bases. Now the great majority of figures are of marble, and nearly all are attached to bases by the feet. These three figures are thus a most peculiar class, of which there would probably not be three in a hundred, or even a thousand average figures.

On enquiry of a guardian at Herculaneum, as to where these bronzes were found, he pointed out the foot of the cliff at the end of the main street that is open. This accords well with their nature. They were unattached, and lighter than the flow of volcanic mud, and would thus be floated off their pedestals by the wave of mud which spread over the town. They would flow forward with it, and falling over on the mud as it fell over the cliff, they would be entangled in the stiff paste and so lie as found, at the end of the wide street down which the mud flowed between the houses.

The conclusion from this fitting of the facts is that these probably

came from among a far larger number of fixed figures and marble figures, which would not float with the mud. And that if the street line be followed up it should lead to the agora, or some other large open site, where the far larger number of fixed statues will be found still in position. I have wished to try this chance for ten years past, but as others now have the opening, I give the clue for what it may be worth. At least a tunnel up the street line would be as good an attempt as any other.

W. M. FLINDERS PETRIE."

Our Consul-General, Mr Neville Rolfe, points out that these bronzes were found in the excavations beneath the garden of the monastery of S. Agostino degli Scalzi mentioned above (p. 39).

Mr Flinders Petrie's suggestion obviously is that where bronzes or sculptures appear to have drifted along definite lines they should be followed up to where they came from, in the hope that many others less easily transported might still be found there; though the example he gave was founded upon incorrect information.

Having discussed at some length these interesting questions arising out of the most recent investigations of volcanic phenomena and their bearing upon our enquiry into the mode of interment of Herculaneum, let us again turn to the interpretation of the accounts given by contemporary writers.

We left Pliny the Elder making for the coast nearest to Vesuvius. He probably expected to be able to ride at anchor in the harbour of Herculaneum, but when he got near the shore he perceived another source of danger. He came suddenly upon shallow water and banks of debris, carried down (by torrents) from the mountain, lying in his course, "vadum subitum, ruinâque montis littora obstantia." It was not that he was in danger of being aground by the sudden retreat of the sea, nor from the vast fragments which rolled down from the mountain and obstructed all the shore. If an earthquake wave had caused a retreat of the sea it would have returned in a huge wave which must have destroyed his fleet. Moreover no vast fragments can have rolled down from the mountain to the sea, and no such fragments are found in the ejectamenta of that eruption.

What really must have happened was that there had been already a tremendous fall of ash, and the steam from the crater had been condensed into torrents of rain, which carried the light ash down the hollows into the sea so that he came suddenly upon shallow water (vadum subitum), while here and there opposite the principal outfalls banks (obstantia littora) were formed, which soon were raised above the level of the sea and formed new shore lines, as it were, facing him and preventing all access to the original coast. This material of small specific gravity so easily transported by the torrents along the valleys and watercourses was in time spread by the action of the wind waves, and still we read on the Admiralty charts "cinders, cinders," out to thirty fathoms depth all along that coast. The plan of this part of the coast given by di Jorio (Plan, p. 38) gives a very good idea of what must have been the general appearance of the shore and the change produced by the immense volume of ash washed down the ravines.

The wind was still favourable and Pliny proceeded to Stabiae where he found Pomponianus anxious to leave but unable to do so until the wind changed. It is curious that we have no mention of the possibility of propelling these galleys by oars.

Vesicular lava and pumice is molten rock full of bubbles of gas by which it has been blown out, as bread "rises" by the development of bubbles within the dough. When fragments of lava are broken up or crushed the gas is given off, and it is probable that in most cases when we read of mephitic vapours and fetid smells accompanying showers of ash, it is the escape of these included gases which has been perceived. We can observe an easy illustration of this on roads repaired with slag. If we break any of the vesicular fragments or notice the effect of heavy wheels passing over it we smell the gas held in the slag.

Anyone lying down on such fragments, especially where newly ejected material was being showered down upon him, would certainly experience great discomfort if he escaped fatal results.

Pliny the Younger gives a very circumstantial account of his uncle's death. He retired to rest and fell asleep, for he was heard snoring. They called him not because there seemed to be any deleterious fumes or any increase in the paroxysmal action of the volcano, but simply because they feared that if they left him there longer he could not get out at all, owing to the accumulation of scoriae and pumice outside the door of his room. Then they had a consultation as to what had best be done. Some were for leaving the house, but the reason given was not that the roof might be crushed in by the weight of ash upon it, but that the whole house might be thrown down by the rapidly recurring earthquake shocks, and when some of them went to where they could get a better view in order to ascertain whether it would be safe to push out to sea they saw that the sea continued raging and tempestuous; that seems to point to submarine disturbances, but we do not find any reference to this as he was putting in to shore off Retina. Though it was day he states that they were surrounded with darkness blacker and more dismal than night, but the landscape must have been lighted up by flashes from the mountain to enable them to see so far out to sea.

It is most probable that the death of Pliny was due to suffocation, caused partly by the fine dust which fell thickly like that which in the eruption of A.D. 1906 succeeded the fall of lapilli at Ottajano. It may have been caused partly also by the noxious gases given off by the ashes on which he was lying and which were still falling around.

The fall, as we have seen above, had been so heavy that his friends and servants roused him and made him leave the house for fear the doors should get jammed and the passages blocked by the rapidly accumulating heaps. But it must have been intermittent both as regards quantity and the size of the fragments, as indeed we see in any section of the volcanic deposits in that area. When his servants returned to look for him they did not find him buried under ash but lying quietly as if he had passed away in sleep with his clothes not burnt or torn. The fine ash and the gas might well have choked a young and vigorous man held down by circumstances, but was

much more likely to be fatal to an elderly corpulent person who already suffered from difficulty of breathing. The whole story is quite consistent with what is recorded of the eruption and with what is seen during excavations.

I cannot accept the story that Pliny was killed at his own request by his servants. There is nothing in the story as told by the Younger Pliny to support it. They were not cut off in any way nor was there anything to suggest imminent or inevitable death, and when they returned they found him lying as if he had died in his sleep. But as I see in so many other parts of this disconnected story a reasonable explanation of many things that appear at first improbable I will suggest a conversation to shew how this story may have arisen.

1st Friend. Have you heard that Pliny is dead? His servants ran away and left him there to die. It was downright murder.

2nd Friend, repeating the story. Have you heard that Pliny's servants killed him by leaving him where he could not escape?

3rd Friend. Have you heard that Pliny's servants killed him when the ash got so thick that they had to fly? They were faithful servants and very fond of him, so I am sure he must have asked them to put an end to his suffering.

And so the story is complete.

From what we know of the usual course of a Vesuvian period of activity I do not think we have much to complain of in the accounts which have come down to us from contemporary or nearly contemporary writers respecting the outbursts of the first century A.D.

We must of course read them with ordinary intelligence as we should accounts of recent eruptions and as far as we can make allowance for the temperament, style, religious views, and social position of our authority.

Dion Cassius, for instance, a flowery and somewhat diffusive writer (I will take the liberty of rearranging his sentences a little to point out what I mean), gives a general description of the mountain and, writing for people most of whom went to some place of worship, he says that clouds rose from the crater like the curling smoke when incense was burnt

before the altar. It crackled and flashed and by night the reflection of the glowing mass in the crater was seen upon the cloud though rarely visible by daylight. He noticed also that an explosion commonly followed when a mass fell in from the walls of the crater, and fragments were blown out by the steam, which produced loud noises in the constricted neck.

These exhibitions of activity, though startling to those who had no experience of such phenomena, were regarded with indifference by those who had seen them time after time. But if all the outbursts of many years had been crowded into one, that would have been a trifle compared with what did next happen. For there were terrible earthquakes so that the sea was driven off the shore, the plain heaved and the peaks leapt, while the sea roared, and bellowings and thunders were heard beneath the ground and echoed from the clouds.

Then suddenly there was heard a terrific crash as if the walls of the mountain had fallen in, and this was followed by an eruption first of large blocks which were hurled forth as high as the highest peaks; then of fine ash which was shot into the higher regions of the air where it appeared like smoke which overshadowed everything so that the sun was altogether hidden as in an eclipse, and it became night instead of day and darkness instead of light.

The people were panic stricken and fled hither and thither; those who were in their houses ran out into the street and those who were in the street sought the shelter of the houses, those who were at sea made for the land and those who were on land took to the sea, thinking anything which was far from them safer than that which was by them.

Some thought the last day had come and that the elements did melt with fervent heat, while others saw in the rising clouds phantoms of giants looming through the smoke.

> Men many and huge—surpassing human size,
> Such as were giants painted, came and went—
> Now on the mountain side, now on the plain,
> Now in the cities seen—by day, by night—
> Wandering on earth and in the sky: while blasts
> Of trumpet sounded war twixt gods and men.

An enormous quantity of ash was ejected which did much harm to man and beast and field; many fish and birds were killed. It buried two whole cities, Herculaneum and Pompeii, and the eruption happened while the people were in the theatre.

The quantity of dust was so great that some of it reached even Africa, Syria and Egypt, while some came to Rome, where it filled the air over the city and obscured the sun. Here too, it caused great fear, for people did not know what had happened (on Vesuvius) and could not guess the cause of the phenomenon. They thought that the end of all things had come, and that sun and earth and sky were being confused and overturned and were vanishing for ever. Though the ash did not at first fall in such quantities as to do much harm it afterwards caused a pestilence. Next year however another fire, not from beneath the earth, destroyed a great part of Rome while Titus was away in Campania looking after the victims of the great disaster there. This reminds us of the great fire of London which followed the plague.

He sent however two men of consular rank (to Rome) to make provisions for those whose houses had been destroyed and ordered that the property of those who had died without heirs should be given to them besides advancing other money.

The fallings of the side of the crater and the explosion immediately after, which Dion Cassius describes, is exactly what happened during the last eruption of 1906, and the appearance first of larger pieces then of fine ash is what is recorded over and over again.

He tells the story of the giants as if he believed it, but many an account of the interposition of saints and the beliefs and ceremonies of to-day in Naples and our names for the Giants' Causeway and Devil's Ditch may after fifteen hundred years require as much explanation as does that coming from one who was probably familiar with Hesiod and the giants of Greek poetry as well as with popular superstitions.

He says that the eruption happened while the people were in the theatre. Had he said this of the earthquake it would have required explanation, seeing that there were no skeletons

found in the theatre of Pompeii or Herculaneum; but the effects of the eruption were not so sudden. When the ash began to fall thick the actors could not go on and the audience would leave the theatre long before it had come down so thickly as to be dangerous.

He mentions that it was the ash that killed the fish, not that the receding sea left them stranded.

The upper currents carried ash far east and south-east as well as north to Rome, and his account clears up the difficulty about the appropriation of the property of those who died without heirs to those whose homes had been destroyed, for he is obviously still referring to Rome not to Herculaneum or any southern city.

Eruptions later than 79 A.D.

Thus we learn from the evidence of eye witnesses that the volcanic activity of Vesuvius in the first century A.D. followed the course of a normal eruption on a line of disturbance. First "tectonic earthquakes," then after a considerable time, in this case sixteen years from the first shock, the lava reached the surface, and produced all the phenomena of an ordinary eruption, namely "volcanic earthquakes" due to explosions, ejection of ash, &c., but that there is no mention of lava flows on this occasion as the lava was blown out, but did not overflow or run out through side openings in the walls of the crater.

But, while we are examining the deposits under which Herculaneum and Pompeii are buried, we must bear in mind that there have been many outbursts since the first century A.D., and both Pompeii and Herculaneum have had many a layer of ash spread over them since that first written record. In the case of Herculaneum, many a lava flow has sealed the covering ash over extensive areas, perhaps not of the town itself, but of the suburbs where the rich villas stood, and where there may be still treasures awaiting the explorer.

This opens up a very important line of enquiry, for we know that Pompeii has suffered ever since its entombment in 79, until it has recently been taken under state protection,

from being so near the surface that valuable building material and artistic treasures could be procured with little trouble by digging down into the soft tuff. Herculaneum has been too deeply buried to suffer in this way in recent times, but we cannot feel sure that Herculaneum can never at any period after its burial in 79 have offered to the collector of works of art opportunities of adding to his treasures, or to the builder material worth excavating at a moderate depth from the surface. The probability of this having been the case depends upon how much ash and lava have been spread over the site during eruptions subsequent to that of A.D. 79.

It is exceeding difficult to estimate the depth of ash that fell over either city in A.D. 79. Successive lava flows can be distinguished and traced, but, only in exceptional circumstances, as for instance where old surface soils have been preserved, is it possible to say whether alternating layers of dust, and ash, and pumice should be referred to variations in the paroxysms, of one great outburst or to eruptions separated by long intervals of time. We know that there have been tremendous volcanic outbursts at various times since A.D. 79, but how much each or all of them added to the covering under which the two cities, and many another of less note, now lie concealed is at present only a matter of speculation. But there have been good observers on the spot during most of the eruptions of the last three centuries and we can learn much from them to help us in our interpretation of the still more remote past and to guide us in our researches among its ruins.

Herculaneum must have been much less deeply buried by the eruption of A.D. 79 than we should infer if we did not take account of subsequent accumulations. As then we have to make allowance for original irregularity of distribution owing to shifting wind currents and transport by rain torrents, &c., &c., we may, on the one hand, hope that shallower places and softer material may here and there be found by the explorer of the future. But, on the other hand, the same facilities must have been presented to a far greater extent to the inhabitants of the first century returning to seek their own or others' property and, though may be in a less degree, have been

met with by the excavators of the seventeenth and eighteenth centuries.

There are only about half a dozen eruptions recorded during the first thousand years and about fifty in the last two centuries, but of these hardly more than a dozen were of first importance. There was a violent eruption in A.D. 203, and another in A.D. 472. This was remarkable for the enormous quantity and wide dispersal of ashes, which reached Constantinople in such quantity as to cause great alarm, so that the Emperor Leo fled from the city and the event was annually recalled by special ceremonies in commemoration of it.

Procopius gives a very interesting account of a great eruption in 512. Another of considerable violence is recorded as having occurred in 685.

There is mention of an eruption in A.D. 983, but little else than the fact of its occurrence. Glabrus Rudolphus, a monk of Cluny, mentions another only ten years later in A.D. 993, and this seems to have been of some severity. Eruptions are recorded in A.D. 1036, A.D. 1049, A.D. 1138, A.D. 1139. That of A.D. 1036 is said to be the first respecting which there is any mention of a lava flow. During the last it is said that violent outbursts continued for eight days, and for thirty days dust and ashes were still ejected so that the crater was quite cleared out and remained so, that is to say, no secondary cone was formed within it, till the eruption of A.D. 1631.

An eruption took place in 1306 and again in A.D. 1500, when the great quantity of ashes thrown out is especially mentioned, and again in A.D. 1568.

The intervals between the eruptions are not of uniform length. The later eruptions seem to have recurred every quarter of a century, but from the nature of the case we cannot expect any regularity. As we have seen above (pp. 43—46) this depends upon a vast number of details of structure, rapidity of cooling, depth, etc., which cannot be depended upon for any numerical estimates. There was a great eruption in A.D. 1500, and then a period of rest till A.D. 1631.

The outburst of Vesuvius in A.D. 1631 was one of the most violent of recent centuries, and is the one which as far as we

can ascertain caused the most important modification of the surface above Herculaneum and over the surrounding district of any of which we have records. We have fortunately in this case a full account written by a careful and competent observer, the Abbate Bracciani. His description of the condition of the crater reminds us of that given of it previous to the eruption of A.D. 79.

Though fissured from end to end and full of masses of broken rock and containing pools of warm water connected with which were sulphurous emanations, it was overgrown by vegetation and even provided pasture for cattle over considerable areas.

Here we must remember that Vesuvius is only one of a group of volcanoes of which sometimes one sometimes another relieves the heated interior of the crust.

These shocks were felt along the volcanic belt that stretches through Vesuvius and Ischia. They were obviously tectonic earthquakes due to deep seated movements in the crust for the volcanoes had not yet begun to be active. But the interval between the first shock recorded and the volcanic outburst was short in this case—only a few months. The ground rose and fell in the great crater. The level of the water was lowered in the wells: a well-known phenomenon due to the fissuring of the rock and the movement of the ground.

> And my soul sank within me, as in wells
> The water sinks before an earthquake's shock[1].

In the morning of December the 16th the outburst took place and the hardened plug and all the surface deposits which had been accumulating for years within the crater were blown out with a terrific noise and hurled forth as from the mouth of a cannon, and when it had reached the height to which the initial force could carry it, the fragments spread, sometimes, owing to a slight deviation from the vertical direction, forming the pine tree described by Pliny; or, when caught by the wind, carried away, the heavier pieces dropping first, the finest obscuring the sky and covering even distant lands with showers

[1] Longfellow, *The Two Angels.*

of volcanic dust. In this case the ash is said to have travelled over the Adriatic and Greek Archipelago, and even reached Constantinople. It is always recognised that there is great trituration of the fragments in such an explosion and much of the finer material is supposed to be formed in that way—some of course is burst by the expansion of the gases within. But if this friction is going on we need not wonder at the production of electric sparks, and lightning flashes are commonly seen in the smoky cloud, and some people were even reported to have been killed by these *ferilli* as they were called.

The lava soon rose till it found a way out of the crater. This also was accompanied by shocks and tremors and rumblings as the lava came in contact with water or combustible material or as masses fell in.

This lava had been well boiled and was very fluid so that it ran quickly down the hollows and spread over the lower ground and, somewhat restricted by the valleys which were more numerous near the coast, sent long tongues of fire even down to the sea.

Earth movements of some intensity were still going on; the result of one was to make the sea retreat half a mile or more and then return in a huge wave which broke over the shore more than 100 feet beyond its usual limit.

This eruption of 1631 is perhaps after the original catastrophe of A.D. 79 of most importance in the enquiry before us.

Earth movements and severe earthquakes were felt for six months before the great outburst, and the sea frequently receded and rushed forward again. The account given by Sorrentino and quoted by Sir William Hamilton describes the normal sequence of events. The lava rose in the crater and the water which it met with was converted into steam, causing terrific noises by the explosion which cleared out the crater, while tremendous rain from the condensed vapour caught and carried the dust in torrents of mud over all the mountain side and adjoining lowlands as far as Nola and even to the Apennines.

There is the usual story of hot water issuing from the mountain but we never get any exact evidence for this. Such

rushes of water as would be produced by the rain storms would probably appear too great to be explained by anything within local experience, and the inference would be drawn that it must have issued from the mountain. It is easy to account for its being hot for it was falling on hot ashes. In a great fire in London I have known the water which had been thrown by engines on a burning building run off warm to the opposite side of the square (see above, pp. 63, 64).

But we must not assume that it is at all a common thing to have large bodies of water discharged from a volcano. The idea has generally arisen from the tremendous rain which is caused by the condensation of the vast columns of steam which are seen to rise with the ash from the crater (see above, p. 56).

The rushes of water on Etna may in many cases be due not only to the torrential rains but to the melting of snow during the eruption, as is recorded by d'Ulloa in the case of Carguayraso in the Andes.

Nor can tuff, like that seen in Herculaneum, be due to a flow of mud from the volcano. The ingredients are not such as occur within the crater except where derived from the small proportion of this finely divided material as falls back into the crater, and when this happens it is generally boiled up again in the seething lava. To reduce it to the state of dust, ash, pumice, cinders, it has to be shot out, made vesicular, or even burst by expansion, triturated in rising and falling and spread in accordance with its specific gravity and size far and wide. Then it can be carried by water and still further sorted and rearranged.

The mud of a mud volcano is a very different thing; it is boiled, stirred by the force of gases and steam, and often has much of its silica carried off in solution. It is reduced to the finest mud and is quite different from the brecciated rock of Herculaneum.

The usual accompaniment of the volcanic eruptions of Vesuvius consists in the formation of ash torrents, locally known as "lava d'acqua" and "lava di tango," and the same kind of deposit is produced whenever exceptionally heavy rain

falls upon the unconsolidated dust and ash. The recent eruption has furnished much material for detailed study by the localisation of the ejected products—thick beds of lapilli in the north-east sector, the breccia with coarse constituents formed in the dry way upon the cone and carried down by avalanches, and the fine dust scattered everywhere on the volcano.

Lacroix has described the mechanism of the production of ash torrents in the course of an eruption. The loose material freshly ejected, always more or less porous, absorbs the rain water from the showers of the upper slopes. If these are very intense, as was the case in the Antilles, a torrent can form immediately; but on Vesuvius in the first days of the eruption the rainfall was localised, intermittent, and slight, and inhibition took place gradually. When it had proceeded sufficiently far, the entire mass commenced to move upon the slopes as a thick mud, which advanced rapidly down the valleys, eroding and transporting much material. The mud lava finally ceased to flow and by its consolidation formed a conglomerate with a chaotic structure. The most simple case is realised when the quantity of rain is not great, but if the rainfall continues there comes a more liquid flood, which erodes the mud that has gone before, cuts into the underlying material, and deposits, on the lower parts of the mountain, sediments with torrential stratification.

The mud lava on the north-east side of the mountain consisted of rather even-grained lapilli united by fine mud. The flow occupying the bed of the torrent of Ottajano, on becoming dry, formed a black mass 8 meters wide by 0·75 meter thick at the front end. The surface was covered with concentric wrinkles like those of viscous lava and longitudinal furrows, indicating the different levels of the stream. It bore a remarkable resemblance to true lava flows. On drying, the surface became covered with a white coating of alkaline chlorides and sulphates that impregnated all the erupted products. Some days later, on account of the persistent rains, the erosive period was inaugurated with its disastrous floods.

The phenomena that I have seen in the production and intermixture of the chaotic formations, accumulated in the dry

way by avalanches, with those produced at their expense "under the influence of water, and the analogy of structure presented by them after drying and settling, are of great importance for geologists who have to decipher the structure of extinct volcanoes, like those of Auvergne. They explain the difficulties of interpretation, often inexplicable, that one encounters in the study of breccias and conglomerates of trachytic and andesitic origin[1]."

The lava which had stood simmering in the crater for some time at last overflowed the lower part of the rim on the side next the sea which it reached at a dozen different points along a frontage of some seven and a half miles, spreading over much of the ash covered slopes around Herculaneum and forming the promontory of the Granatello. (See Map, p. 32 and Plan, p. 38.)

It was after this eruption that Braccini and P. Ignatio record that they picked up sea shells on Vesuvius, and the inference drawn was that great bodies of sea water had got in and been ejected during the eruption. But this needs confirmation and explanation.

In A.D. 1660 an eruption occurred which it is important to note with a view to the particular question before us, because of the great quantity of ash thrown out. Sorrentino gives us some data for estimating how great it must have been. He says that the interior of the crater was blown out, so that there was an abyss, as well as he could estimate it, two thousand paces deep, with sides so steep that you could not get down anywhere.

After this volcanic disturbances are more frequently recorded, but it does not follow that they were of more frequent occurrence; indeed it was remarked by one writer that the people hardly noticed the smaller outbursts from which no immediate danger was apprehended for themselves or their city. Small eruptions, says Sorrentino, there may have been, however, for such have hardly ever been counted or kept in memory. Many details of interest are mentioned, some by one some by another. For instance no rain fell during the eruption of 1682, and it was observed that the dry ash did little damage

[1] Lacroix, "Eruptions of Vesuvius in 1906," *Rept. Smithsonian Inst.*, p. 240.

to the fruit crop as compared with that of A.D. 1707 in which heavy rain accompanied the outburst, but we must remember that it added to the depth over the already buried cities.

The outbursts between this and A.D. 1689 caused many changes in the cone, and in 1694 there was a very considerable flow of lava. This eruption lasted fifteen days and threatened Resina and Torre del Greco. In 1696 the volcano was active and, in 1697, 1698, there were very violent eruptions with earth movements, which greatly disturbed the waters of the Bay of Naples, followed by overflows of lava, which ran down towards Resina, and finally a tremendous explosion from the choked crater. In these accounts we continually read of lava streams overflowing the rim of the crater or rushing out of apertures in the sides and uniting or dividing as they fell into the hollows and valleys formed between previous, but then cooled, lava flows. From this time on for a hundred years Vesuvius never ceased to shew signs of activity. Sometimes the outbursts were of great violence and often the lava nearly reached the sea. Sometimes there are small differences in the character of the lavas depending upon the source and depth from which they had come, their rate of cooling, &c., which enable us to identify isolated parts of these ancient flows and trace their course. Nor does the record of the mountain's activity cease here, for we read of constantly recurring outbursts throughout the next two centuries also. Perhaps we may notice that the intervals between the eruptions have been rather longer during the later period, but, in respect of this also, we may take account of the better sense of proportion arising out of fuller knowledge in the later observers. Full and careful records did not exist before the time of Serrao, Sorrentino and Della Torre, and exact observations we may say commenced with Sir William Hamilton, stimulated by the criticism and encouragement of the Royal Society. Sir William himself points out that many even of the more violent eruptions would have been forgotten if the priests had not preserved the record of the exhibition of sacred relics and the interference of various saints.

In thus reviewing the fuller accounts of later writers we

cannot but have the conviction forced upon us that the negative evidence as to the small number of eruptions during the first fifteen centuries of our era is misleading, and that there must be many and great outbursts unrecorded,

Carent quia vate sacro.

The outcome of this short sketch of the scattered notices of the earlier eruptions and a glance at those more fully described during the last three centuries is to impress upon us that in any exploration on the slopes of Vesuvius we must expect to find an enormous quantity of volcanic material that has been spread over the area since the first century A.D., and to distinguish this from the deposits of the first century and thus arrive at some idea of the condition of the surface immediately after the catastrophe of 79 A.D., is, as I have already urged, of first importance for our guidance in future excavations.

Seeing that we have reason to believe that at least as much ash has fallen since the first century A.D. as fell in A.D. 79, the first thing to do is to endeavour to distinguish between the successive eruptions. If we could find at the bottom of a layer of ash just enough pottery or other relics to enable us to identify it as belonging to the seventeenth century or earlier, that line should be traced with the greatest care. In this way we might feel our way back into the more remote past and perhaps somewhere make out upon satisfactory evidence how deep some part of Herculaneum was buried in the eruption of A.D. 79. If we could find anywhere such a base line and trace it to where we have reason to believe the ground rose and the original covering was not so deep we might make out how it was possible that some of the inhabitants returned and lingered about for ages. Tentative research by shafts, by finding and following roads, sea-walls, &c., is obviously one of the methods to be adopted, but we may also suggest that an attempt to disentangle the various strata that now so irregularly cover the city and its surroundings that are not from the nature of the case likely to differ in mode of origin, depth and composition, and to trace and record all the observations bearing upon this question, would be one of the most suggestive, and one of the

most likely to reduce the labour and expense of further exploration.

THE MATERIAL IN WHICH HERCULANEUM LIES BURIED.

Having considered the history of the volcano so far as seemed necessary in order to interpret rightly the notices of early writers and having examined the geology and physical geography of Herculaneum and the surrounding district, let us now push our enquiries further and see what is the character of the accumulations under which the city lies buried, being careful not to call in any *deus ex machina* or any hypothetical explanation which is contradictory to what we have learned is the normal sequence of events in this volcano and what we have so far found quite consistent with the observations of all the most skilled observers whose works have come down to us.

First to clear up some misapprehensions and difficulties arising out of a nomenclature which is partly borrowed from current language and partly technical.

It used to be commonly said that Pompeii was buried under ashes and Herculaneum under lava. This was probably suggested by the great masses of lava belonging to the eruptions of A.D. 1631 which ran down the rich slopes north and east of Herculaneum and probably did flow over the ash under which many a splendid villa lay buried deep. This view was strengthened when it was reported as the result of excavations that it was difficult to extract the treasures of Herculaneum because the ground in which they were buried was so hard. But the lava of A.D. 1631 and of 1794 (see map) did not touch the villas which had been buried centuries before under a vast accumulation of what probably fell as dry ash, except where caught by the rain. Nor did these later lava flows go near the town, because as we have shown (pp. 36—39) when a stream of lava cooled, it formed a ridge on which the towns and villages were afterwards built and subsequent flows did not follow the ridge, but the hollow ground on either side of it.

By and by it was realised that Herculaneum had not been originally overwhelmed by lava but by a volcanic ash which

had become consolidated and was in places exceedingly hard. This material is known under various names: tuff, volcanic tuff, tufo, tufa, peperino, trass.

Tuff is the word most commonly used when the ash is so far consolidated as to break into lumps. Volcanic tuff was introduced because the word tuff was applied also to calcareous tuff or calc-tuff, as it is abbreviated, which is the same as travertine. This is the more or less porous rock formed by the precipitation of the carbonate of lime from such waters as those of Tivoli the ancient Tibur, from which "Lapis tiburtinus," shortened into "Travertino," was derived. It owes its porous or vesicular texture to irregularity of deposition or the occurrence of vegetation, moss, grass, &c., over which the saturated water splashed. Although volcanic conditions are favourable for the formation of travertine, there is nothing volcanic about it, and it may be formed under a bridge, in a cave, or anywhere. It was once proposed to apply the Italian word tufo to the volcanic tuff and tufa to the calcareous tuff, but the suggestion has not found favour. Ordinary volcanic tuff is often very calcareous from fragments of limestone thrown out with the ash or the carbonate of lime interstitially redeposited, and the consolidation of the ash into a hard cement, or even less hard but still solid mass, depends among other things upon the presence of this lime. Trass is the German word used in exactly the same sense as volcanic tuff.

What we have to consider in Herculaneum is *tuff*.

The deposits which cover Pompeii are simpler and more easy to examine and yet belong to conditions so similar to those which we have to do with in Herculaneum that we must refer to them. Pompeii was built upon the rising ground formed by a great lava flow but no lava has ever invaded the city. There was no lava flow in A.D. 79: all the lava was blown out, and it has been observed that the pumice of A.D. 79 appears to be made not of ancient debris like the scoriae of 1906 but of new magma. The dust and ash and pumice shew distinct stratification, but there is nothing to give us the date of the several layers. Over some parts of the ruins we find traces of ponds and the components of the ash sorted by water.

When we have a layer composed largely of leucite crystals we may explain it by supposing that the material had been resorted by water or that a loosely compacted lava containing leucite crystals had been blown into the air, when of course the solid crystals would fall faster than the ash and therefore be arranged in separate layers. There is a good example by the house in Pompeii with the amphoras built into the wall. Here also we see evidence that the ash was consolidated after it had fallen, and that it is not necessary to suppose that every hardened mass was once a sort of mud river, for there are plenty of sections in which the upper part, as far as the rain water had soaked in, is a fairly solid tuff while the lower part is a loose dusty ash.

Now if we turn to Herculaneum we find the same thing, some of the tuff is hard and solid while some can be easily scraped away with a knife. In the wall of rock left around the new excavations on the side nearest the sea the material is a dark red or gingerbread coloured mass that stands easily in a vertical cliff fifteen or twenty feet high, but is easily cut. Of course where such a deposit has got wet and hardened against mortar and plaster it unites with it so that large pieces of the wall and adjacent tuff break away together.

The tuff which has buried the theatre is similar and most of it can be quarried or removed from sculpture or other objects of interest without difficulty and without injury to the marble or bronze. These great masses of ash are of a very uniform degree of coarseness, more so than we should expect in such a material had it been showered down in one or in many eruptions, but we do find that after the first winnowing has taken place in the upper regions of the atmosphere there is a great uniformity in the finer portions, and when, in addition to this, we have reason to believe that the falling and fallen ash was caught and carried down the slopes and hollows by the heavy rain we see that a further sorting must have taken place and the deposit is just such as would be produced by continuous accumulations of rain-wash, in which the water would have picked up and transported to the same place ash of the same size and texture. The loams left by flood water and the ordi-

nary rain-wash at the bottom of any slope are generally very uniform in texture, except where lines of coarser material have here and there been washed out and carried along by gushes of greater velocity and power, and such lines of larger fragments are not unknown in the tuffs of Herculaneum. If as we have above explained there is reason for believing that the theatre stood at the bottom of a "Vallone" close up to the south-eastern side, here, if anywhere, we should find evidence of the rain-wash from the higher ground. The massive building would catch and hold it, and the water running down the streets would here gather in greatest force. Accordingly here we see that the tuff is of generally uniform texture, but contains here and there lines of larger fragments. Mrs Hughes found here *in situ* near the base fragments of pottery and broken brick imbedded in the tuff, and, in the holes and corners, masses of debris lie heaped together. There is no evidence that this is due to any outburst of mud, or even water, from the mountain. This sort of tuff could not be formed in the interior of a volcano. It is ordinary rain-wash such as might be produced to-day if a heavy shower fell on unconsolidated ash. From these observations also it is clear that Herculaneum is buried, not under lava, rarely under natural cement, but generally under locally more or less consolidated tuff.

We must remember the manner in which the ash falls, and what happens to the various kinds of building as the ash is heaped up. When the ash had been falling for some time the weight on the roof must in many cases have proved more than it could sustain, and the roof and floors must have been crushed down. This happened in the eruption which took place in the early part of this year. The covered market and other buildings in Naples suddenly collapsed, owing to the weight of the ash which had accumulated on the roof. But in Herculaneum and Pompeii much ash would have got in before this happened, for many of the Roman rooms were wholly or partly open to the air, and the ash fell and was blown about, entering through doors and unglazed windows, down chimneys and skylights, insinuating itself through the smallest hole or crevice, like the

sand in an hour glass, and filling up the rooms and every cranny and corner in them.

We are able to see by the manner of occurrence of the ash and ruins whether the houses had been partly destroyed by the earthquakes which occurred at the commencement of the outburst or had been crushed down by the weight of ash that fell later. If the earthquakes had shaken down the upper part of the houses before they were buried, we should find the ruins on the floor and the ash above them, but the floor of the houses is generally deeply covered by ash. If the ash had partly filled all the accessible rooms before the roof and partitions broke down, the fine dust would cover the floors and the ruins rest upon it at a higher level. This seems to have been so commonly the case at Pompeii, that we must infer that the true explanation is that the houses were not crushed down until a good deal of ash had got into the lower rooms.

The uniform level to which all the buildings are reduced in Pompeii is partly due to this cause, and partly to the work of subsequent excavators seeking building material. There was an average depth down to which it paid them to dig, but owing to the depth and mode of interment Herculaneum could not suffer to the same extent in this way.

When we are examining the ruins of cities that have been buried under lava or ashes or mud, or been overthrown by earthquakes, or have crumbled down under tempest or decay, or have been despoiled by man, we must in each case take account of many different agencies simultaneously or successively at work.

The ordinary operations of nature have not ceased since the great catastrophe of A.D. 79. Not only have there been recurrences of volcanic activity, but we have to consider also the action of the wind, rain, and infiltering waters in rearranging and modifying the material that covered the city. Water has gathered in the hollows, and soaked into the pozzuolana here and there, sometimes hardening it, sometimes causing its decay. Inequalities have been filled up by rain-wash or wind-borne sand and dust, and these deposits are hard to distinguish from the ash that fell in A.D. 79.

There are also sections, as for instance that within the area of the house in Pompeii with the row of long narrow amphorae in the upper part of one of the partition walls, in which there are alternations of fine black comminuted lava and layers of larger fragments of pumice. It is not always easy to form a decided opinion as to whether such deposits owe their stratified character to the showering down of fragments of various size and specific gravity from great heights, or whether some of them may not have been sorted by the rain water which was such a usual accompaniment of volcanic outbursts. There are, however, very few deposits of ash now seen in Pompeii which have been consolidated by moisture converting the ash into cement. Perhaps they have not the proper texture or the due proportion of lime or iron oxides or other ingredients to cause it to set readily. Some beds in this section consist largely of crystals of leucite which have no tendency to cohere—and some are full of land shells—which, of course, have been washed off the surface.

After that great catastrophe Pompeii and Herculaneum must have been represented by groups of mounds, and projecting ruins must often have been covered up in later times by the light ash lifted by the wind. Layard says that he sometimes found the remains of Nineveh covered to a depth of 20 feet by fine sand and dust blown from off the plains and mixed with decayed vegetable matter.

These considerations incidentally direct our attention to sources of error in collecting buried objects of chronological value. We must be very careful in such cases to watch the nature of the covering accumulation because when we have to do with sand or dust for instance we find that large and heavy objects are not blown away, but roll to the bottom of the hollows thus formed, while the light sand is shifting to and fro with the swirl of the wind. Thus objects of very different age are found lying together, as in the case of the Culbin sands, near Nairn, where flint arrow heads and coins of the 17th century are found in the same deposit at the bottom of the hollows between the shifting dunes.

We must bear in mind too that there is much in modern

Italy like what was there in the first century, and sometimes old Roman roads have continued in use to the present day. It is of some importance, therefore, to observe such things closely to see whether we can detect any method of discrimination. In the ancient roads we generally have the great blocks of lava of various forms and sizes fitted together irregularly by selection of natural forms, but where the modern streets are paved with similar material the blocks are dressed so as to lend themselves to a regular arrangement. Sometimes, however, as in the Civil Forum at Pompeii we have a pavement of large squared stones. In repairs of ancient paved roads the modern workman is apt to run into a linear arrangement of the blocks.

Many a mediaeval and recent road has been buried in later outbursts and will be exposed again when the exploration of Herculaneum is being carried out.

As is well known water, at a temperature sufficiently high to dissolve the silicates, carries the silica with it in solution until it reaches the surface where the silica is thrown down and builds up cones and fort-like structures such as are seen around a geyser. When, however, it carries the disintegrated rock in suspension, a viscous mass is seen in the depths below, advancing and receding as the steam accumulates or escapes. Such a mud volcano occurs a few miles below the Yellowstone Lake, at the north end of the Rocky Mountains, and the muddy outpourings of Maccaluba[1], in Sicily, appear from the descriptions to be the same sort of thing.

It is important for us to make sure that this is not the sort of material that we have to deal with at Herculaneum, for it is fine, homogeneous and compact, and if hardened would be very troublesome to excavate, but there is nothing of the kind at Herculaneum or anywhere in that region.

There are also sometimes great and sudden inrushes from a lake or the sea into the depths of a volcano, and a subsequent violent ejection of large bodies of water.

If there has been a great deal of ash falling back into the

[1] Freeman, E. A., *The History of Sicily from the earliest times*, Oxford, 1891.

crater, it may be caught and carried out by water, and the ground outside, with trees and other vegetation, torn up as in ordinary floods, and wood and sods hurled along, and, where the velocity of the water is checked, the debris thrown down, as was seen in some of the great eruptions of Cotopaxi, and more recently in those of the West Indies.

But there is no sign and no record of there having been anything of the kind on Vesuvius, and the material, as we shall see, does not agree in character with what we should expect such an outburst to produce.

There is another class of deposit of far more common occurrence in connection with volcanic eruptions. The lava which is blown in fragments up into the air, shattered by the explosion, burst by the expanding gases, and ground by trituration of fragment against fragment forms a cloud of ash which settles around the cone or is carried by air currents far and wide.

Much of it comes down dry, and is hot or cool according to the distance it has travelled, and the proportion of ash in the air.

Herculaneum has not yet been much explored, and we have, in this case, as in some others, to appeal to Pompeii for the proofs of the character of the eruption that destroyed them both.

Now in Pompeii it is clear that the material was a fine volcanic ash and light pumice, which was carried by the wind and dropped quietly on to the city in the midst of its life and activity. It would not appear that many lost their lives, and of those that did some probably had taken refuge in their cellars and thought that it would pass like a thunderstorm. Some remained from indecision; some, like plunderers in a burning city, risked and lost their lives. Dogs were left chained, horses tied up, and perished.

There does not seem to have been any sudden destruction of life by poisonous gases at Pompeii, for in that case the bodies would have been found lying prostrate, and the limbs flat on the ground, as they could not have been held up after death. But in the casts of bodies from Pompeii we see the arms and legs sustained in various rigid postures. The only explanation

is that while trying to avoid breathing the dust-laden air with some deadly vapours still tangled in the ash, and included in the vesicular cavities, they had thrown themselves down or sunk exhausted; but when they lifted arm or leg as the ash was covering them up, the limb was supported by the dust that fell around, and they could not draw it in again, so that they are found in positions that they could not have retained after death on a flat surface. These bodies shew no marks of having been killed and then buried in ash, but of being suffocated by the ash as it gathered round them.

In the eruption of Vesuvius in the early part of this year the cloud of choking vapour sometimes poured down the hill side and we were once nearly overpowered by it. So it is probable that similar currents rushed down in the still greater eruption of A.D. 79. Indeed Pliny tells us that it was so, but everything points to the conclusion that both Pompeii and Herculaneum were overwhelmed by ordinary volcanic ash, but there is no evidence that it was very hot. Small fragments that fall round the crater to-day are so hot that you cannot pick them up: large pieces are shot much further without losing their heat, and Pliny found as he approached the coast that the cinders were larger and hotter than further out; but fine ash soon gains the temperature of the air. Where it has come but a short way, and is so thick that it has raised the air in which it is to about its own temperature, it becomes a scorching blast of air with hot cinders in it; but there is no evidence that anything of this kind reached Herculaneum or Pompeii during the eruption of A.D. 79.

The decomposition of the bodies tended to harden the immediately surrounding material into a mass, which formed a mould, into which plaster was poured, which took a cast, giving the exact form and position of the body which once filled it, and we see in them no sign of their having been buried in hot ashes. The fists appear to have been sometimes clenched, but the attitudes are those of persons being choked and tossing their limbs about, rather than those of persons drawing their extremities in from burning cinders.

The other objects found point to the same conclusion. The

bread, fruit, &c., &c., is charred, but not by fire. It is altered without any crisping or crumpling. It is uniformly changed by the same kind of slow oxidization which has altered the grain and other food of lake dwellings into charcoal. There are honeycombs, the forms of which are perfectly preserved, whereas the wax must have been melted had it been subjected to any considerable heat. It is in the same condition as the wax on the wax tablet which I have described from dry rubbish under buildings on the edge of the King's ditch, Cambridge.

If wood or other similar substance is burnt in a closed kiln it is reduced to charcoal, but much the same effect is produced by a kind of slow combustion if it is buried in a damp soil. From an examination of the specimens only, it is often difficult to say to which process the change is due, and we must have regard to the surrounding conditions.

The experience of the recent earthquake of San Franciseo explains how fires arise from falling houses, but the conditions of Herculaneum were very different from those of the American city, with its abundance of wood, electricity, gas and oil.

In one of the apartments excavated under the garden of the monastery of S. Agostino degli Scalzi, that is in the Casa dei Papiri, shelves were found filled with what looked like small uniform pieces of wood reduced to charcoal. They appeared to show the rings of growth, and were at first thought to be charcoal for firing. They were therefore supposed to be of no value, and only some of them were preserved. It was, however, afterwards found out that they were rolls of charred papyri, and by placing them on glued paper they were unrolled and deciphered. It was worth some trouble and cost to have obtained well authenticated MSS. of that date as we were reminded by the interesting description of the Greek characters preserved on the papyrus rolls which was given here by the Sandars Lecturer on Palaeography on March 4.

Now if we are right in our inferences from the facts observed in Pompeii we cannot explain the condition of these Herculaneum papyri to anything but slow subterranean oxidization—and we must treat them and other objects found here as waterlogged and soaked, not as burnt. We may hope that

further investigation may prove that other perishable material found charred in Herculaneum has not been subjected to the action of fire or hot ash, but to the less destructive influence of slow oxidization when buried.

If we look at the position of Herculaneum and Pompeii relative to the mountain and higher ground generally, we see that Pompeii has and would then have had little water flowing from the gently sloping surrounding area. Yet we see in some of the sections that the material has been resorted by water.

Herculaneum, on the other hand, is closer to Vesuvius, and torrents of rain caused by the condensation of the vapour given off by Vesuvius, gathering on the hill side above the city, must have rushed seaward over the lower ground on either side of the city, along the streets, and down every slope.

The first flush would sweep them clean of everything that was loose. The newly fallen ash would be churned up in the seething flood and would soon choke all artificial drains and outlets, and stand where arrested by the shape of the ground in a pasty mass which took long to part with its moisture. The ash that fell would be wetted as it fell. Lime would not be wholly wanting, for the crater of Vesuvius rises through tertiary limestones which were being calcined and ejected and dissolved, and iron oxides are conspicuous everywhere, while uncalcined fragments of limestone are abundant in the tuff. What wonder then that some of this heaped up and pressed and slowly desiccated ash should become consolidated into something like concrete. But there is no reason for believing that it was all of the same character, and as a matter of fact we see that it is not.

These outbursts and downfalls were not continuous nor of uniform intensity, indeed we are told that the dark cloud passed over Misenum, but did not at first deposit much ash there. There were, as I have pointed out above, changes of current, and the ash must have sunk into a lower atmospheric stratum, travelling in different directions, as we learn was the case in the recent eruption in the West Indies, where people were surprised to receive a heavy shower of ash from the side remote from the crater.

Fragments of marble, of brick, of pottery, and of wood are buried in the ash that fills the theatre. It was here that my wife found the characteristic pieces of Roman ware *in situ* in the very lowest part of the building, and on the table there are samples of the same tuff containing various fragments of building material.

The reason why there is so little is that the bricks and pottery were heavy, whereas the vesicular lava and pumice and the ash derived from them were very light, so that they did not often get sorted together.

If then Herculaneum is buried in ash which fell directly all over the city and by rain-wash, made up chiefly of this ash, which filled the hollows, and even choked the harbour so as to prevent Pliny from getting near the shore, from the nature of the case some will be consolidated and some not.

Surely the method which is most likely to lead to satisfactory results is to test the ground over definite areas by borings and shafts, and to begin to dig in the softer less consolidated portions, until some indications of thoroughfares or of important buildings may encourage more complete excavation.

Pompeii had water communication with the sea which was cut off, perhaps by earth movements as well as by the accumulation of ash in the channels.

Herculaneum was a seaport and must have had wharves and landing places which, in "the tideless dolorous midland sea," would mark sea level very closely, the differences being due more to wind than tide. They must have been in direct communication with the inland thoroughfares. One such road runs up by the house of Argo, a group of buildings which shews something of the importance of the town of Herculaneum.

I should advise exploration along the sea front with a view to determining all the principal routes from the harbour inland. It will probably be found that some lead to the business part of the city and some to what may be called the residential part.

I would at the same time secure the vineyard south and east of the house of Argo. I learned that the probable price

of this would be about 1500 lire per 100 square metres, as it is agricultural land and not built upon or likely to be wanted for that purpose at present. But I see no indication which would make it desirable to begin by removing the tuff over the whole of this area, unless the excavations along the sea margin suggest a likely line of advance.

I would follow the road already known to rise inland from Argo's house and also try to find the principal routes to the theatre, and reopen the excavations made by Charles III.

But first of all I would prove the ground by digging trial holes all over the site.

Monday, 3 December 1906.

W. M. FAWCETT, M.A., Vice-President, in the Chair.

The following vote of condolence on the death of Miss Mary Bateson was proposed by the University Librarian, Senior Vice-President, seconded by the Master of Peterhouse, and supported by James Bass Mullinger, Esq., and carried:—

> "The members of the Cambridge Antiquarian Society are deeply sensible of the loss the Society has sustained by the death of Miss Mary Bateson, and they desire to record an expression of sincere sympathy with Miss Bateson's family in their bereavement."

The Reverend ALEXANDER CAMPBELL YORKE read a paper on

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