19. *THE HISTORY OF VOLCANIC ACTION IN THE PHLEGRÆAN FIELDS.*

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[PLATES XXVI-XXVIII: MAPS & SECTIONS.]

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I. INTRODUCTION.

THE scene that discloses itself to the observer who enters the Bay of Naples by the so-called Bocca Grande, presents three parts, each characterized by distinct features. On the right, masses of calcareous pink and white rock rise up into the Island of Capri from the foam-flecked waters of the Mediterranean, and stretch through Sorrento and Amalfi to the cloud-capped Apennine. On the left, a vast succession of undulating ridges of tawny-coloured tuff begins, first at the Island of Ischia, and then, extending through Vivara and Procida, spreads out into the gentle declivities upon which Naples is built. In the central background looms grand and solemn the smoking peak of Vesuvius.

Just as these three components of the landscape are diverse in aspect, so too are they diverse in geological origin and constitution. The island of Capri and the peninsula of Sorrento are made up of a gigantic pile of dolomitic and calcareous deposits of Upper Triassic (Hauptdolomit) and of Cretaceous (Urgonian-Turonian) age. Upon these rest in places a few insignificant patches of Eocene-Miocene Flysch. Vesuvius is a typical volcano of concentric accumulation (*vulcano a recinto*), almost entirely built up of leucotephritic, fragmental, and lava-form materials. Between Naples and Ischia lies a vast and complex assemblage of extinct craters, which have erupted much fragmental material but little lava, generally of a trachy-andesitic character, though exceptionally the crater of Vivara has disgorged a basaltic magma.²

This region, more especially that portion of it lying between Naples, Cuma, and Miseno, received from the early Greek colonists the name of the Phlegræan Fields. These men, as they beheld the titanic warfare between the subterranean volcanic forces and the calmer agencies of the atmosphere, pictured it as a great battle

¹ Translated by the Assistant-Secretary.

² G. de Lorenzo & C. Riva 'Il Cratere di Vivara nelle Isole Flegree' *Atti R. Accad. Sci. Napoli*, ser. 2, vol. x (1901) no. 8.

GEOLOGICAL SKETCH OF THE BAY OF NAPLES

Scale of 1 : 500 000.

Quart. Journ. Geol. Soc. Pl. XXVI

Sedimentary Plateau	Tertiary Flysch.	Chiefly basaltic.
	Cretaceous Limestones.	Chiefly lacustrine.
	Hauptdolomit (Trias).	Chiefly trachytic.

Inclination of rocks.

Lines of the principal faults.

SECTIONS ACROSS THE BAY OF NAPLES

Quart. Journ. Geol. Soc. Pl. XXVII

Campi Phlegraei

Bay of Naples

Penisola di Sorrento

1443

N.W.

S.E.

Scale of 1:500,000

- Volcanic
- Tertiary
- Cretaceous
- Triassic

N.W.

Ischia

792

Bay of Naples

-1000

-200

-1000

Capri

585

-1000

S.E.

SECTIONS ACROSS THE CAMPI PHEGRAEI

N.W.

Via Campana

251

Astroni

Agnano

Fosillipo

S.E.

Scale of 1:100,000

W.S.W.

Averno

Monte Nuovo

Cigliano

Astroni

Agnano

Camaldoli

498

E.N.E.

Products of the 1st Period.

Products of the 2nd Period.

Successive products of the 3rd Period.

GEOLOGICAL SKETCH OF THE CAMPI PHLEGRAEI

Scale of 1 : 100 000.

Quart. Journ. Geol. Soc. Pl. XXVIII

between the giants and the gods, terminating in the ultimate victory of the latter.

In the month of March 1903, I made some memorable excursions in this region with Sir Archibald Geikie, who urged me to give a summary of the results of my researches into its volcanic history, which might be submitted to the Geological Society of London. In now complying with this request, I am not unmindful of the many errors and omissions to which the student of so complicated an eruptive area is liable, an area wherein every new excursion propounds fresh problems and suggests unsuspected mysteries.

In order to trace this volcanic history with most satisfaction, it is desirable, first of all, to understand the geological structure of the great basin of the Bay of Naples, in which the eruptions have taken place.

II. ORIGIN OF THE BAY OF NAPLES.

The same rocks as those which form the backbone of the Apennines constitute also the fundamental skeleton of the Neapolitan area: that is, Upper Triassic dolomites, Cretaceous dolomites and limestones, Flysch (Eocene-Miocene) sandstones and marls. These strata, the combined thickness of which is some 3300 feet, have been dislocated and fissured by the post-Eocene orogenic uplift of the Apennines.¹ While this upheaval contorted the softer deposits of the Flysch into innumerable narrow folds, or left patches of them imprisoned within and pinched into the fissures opened up in the underlying Mesozoic formations, the rigidity of these last-named rocks formed a sufficient obstacle to their plication into tightly-packed folds. Consequently they were slightly curved into broad domes and large basins, which in their turn were fractured by dynamic agencies, and the dismembered masses slipped along the fracture-planes, step-faults, etc. being thus originated.

One of these fractured basins is precisely the great calcareous hollow which, sweeping round from the Island of Capri and the Peninsula of Sorrento past the hills of Nola, Caserta, and Capua, and projecting again into the sea at Massico, embraces, as within one colossal amphitheatre, the entire Campania Felice. In Capri and Sorrento the strata dip north-westward, at Caserta westward, and at the Monte Massico south-westward. Thus they form a synclinal depression, the major axis of which, trending north-west and south-east, is some $43\frac{1}{2}$ miles long. The entire rim of this great basin is broken by huge longitudinal fractures, striking sensibly parallel with the Apennines (from north-west to south-east); and by transverse fractures perpendicular to the first-mentioned, and therefore trending south-west and north-east.

But the present configuration of the Apennine country is no longer such as it was broadly outlined by the post-Eocene uplift.

¹ For this and the subsequent observations, see G. de Lorenzo 'Studi di Geologia nell' Appennino meridionale' Atti R. Accad. Sci. Napoli, ser. 2, vol. viii (1897) no. 7.

That uplift, towards the end of the Miocene Period, raised our mountains to a level probably higher than the present one, and thus exposed them to long-continued denudation. In this way there gradually disappeared from the summits of the great broken calcareous massifs every trace of the softer Eocene and Miocene sediments, which nevertheless remained sheltered in the wide and deep synclines, and were mantled over by later deposits.

After the great uplift, this region was subjected in Pliocene times to another depression, and the sea flowed in again over the mountains. Thus it is that we find the great Pleistocene terraces carved out on Aspromonte up to an altitude of 4265 feet above the present sea-level, and in the remainder of the Apennines up to 3280 feet and more.

But when the Pliocene age came to an end, a fresh uplift marked the beginning of the Pleistocene, an uplift which is still in progress, and has been and is accompanied by seismic phenomena and by the active vulcanicity of the Southern Apennines. To such vicissitudes also the fundamental structure of the Bay of Naples has been subjected.

Confining ourselves to that portion of the area which lies nearest the volcanic formations, that is, to the Peninsula of Sorrento and the Island of Capri, we find there (as before stated) dolomites and limestones of Triassic and Cretaceous age. The Tertiary deposits have been all but completely swept away by the long-continued post-Eocene denudation, a mere patch of Eocene-Miocene Flysch now surviving on the highlands between Amalfi and Castellamare di Stabia; while another, rather larger patch, lies amid the lowlands of Sorrento and Massa, in the hollows formed by depression. Not a remnant is now left among these hills of the Upper Pliocene or the marine Pleistocene; but the blocks thrown up from the old crater of Vesuvius¹ and the artesian wells dug in Naples (at the Royal Palace and on Piazza Vittoria) prove that such deposits, containing shells nearly all of which are identical with species now living in the Bay, occur at the very bottom of the basin, beneath the deposits of volcanic material, at little more than 650 feet below the present level of the sea. We may, then, conclude that the volcanic eruptions of the Neapolitan area began somewhere between the end of the Pliocene and the beginning of the Pleistocene Period, upon the bottom of a great synclinal basin, resembling those to be seen elsewhere in the Apennines, but in part drowned by the sea.

The southern rim of this basin now projects above the waters, in the shape of the Island of Capri and the Peninsula of Sorrento. But, just as the various elevations and depressions of both island and peninsula are primarily due to the transverse and longitudinal fractures, which have broken up the calcareous massif into so

¹ H. J. Johnston-Lavis 'The Ejected Blocks of Monte Somma' *Trans. Edin. Geol. Soc.* vol. vi (1893) p. 314.

many fault-blocks, subsequently sculptured by atmospheric agencies: so do the Island of Capri and the Peninsula of Sorrento themselves in reality form part of a single great calcareous mass limited by the submarine contour of 3280 feet, and measuring at least 7870 feet from top to bottom, of which thickness only about 4590 feet now emerges from the waves (see Pl. XXVI).

This great mass is followed on the north-west by a second, which rises from the 3280-foot submarine contour to about 650 feet below sea-level (see Pl. XXVI & Pl. XXVII, section); and this is divided from the first by an embayment, which in all probability corresponds to a valley of transverse fracture, analogous to all the others known elsewhere in the Apennines. The character of the contours, more precipitous on the south and more gentle on the north, suggests the inference that in this submarine massif, just as in the Peninsula of Sorrento, the strata dip from south-east to north-west, and are cut off by a great fracture on the south-east. In this second mass the marine Tertiary and Quaternary sediments have been naturally better preserved, because they were more protected from erosive agencies. The blocks ejected from Monte Somma have furnished abundant evidence in favour of this conclusion.

To sum up then, the bottom of the Bay of Naples, originally moulded by the orogenic post-Eocene folding and by the post-Pliocene uplift, is chiefly composed of two great masses of limestone and dolomite, intensely fractured and dislocated, the constituent strata of which dip en masse towards the foci of eruption. This synclinal dip of the strata towards the volcanic centre, observable also in the Monte Vulture,¹ and at other localities, is doubtless favourable to eruptive phenomena, perhaps for the reason that it carries deeper down the dislocated material, which then becomes subject to powerful thermal agencies with the consequent production of an igneous magma. This hypothesis is, to some extent, confirmed by the fact that in the neighbouring Gulf of Salerno, where dislocations are both more considerable and more numerous than in the Bay of Naples, but in which the arrangement of the strata is anticlinal, there is not the faintest trace of eruptive phenomena. Whatever may be the origin of the deep-seated magma, certain it is that the Pleistocene submarine eruptions emerged above the sedimentary masses, dislocated and folded into a basin, in the Bay of Naples. First came those of Ischia and of other crateriform vents, which built up the whole Campanian plain with sanidine-bearing materials, which are also found heaped up at Sorrento and Capri, and along the range of the Southern Apennines. These discharges were followed by a less widespread phase of vulcanicity, represented by the trachy-andesitic rocks of the Phlegræan Fields and the leucotephritic material of Vesuvius. While, however, at the Vesuvian vent the eruptions have discharged fragmental and lavaform materials from one single

¹ G. de Lorenzo 'Studio geologico del Monte Vulture' Atti R. Accad. Sci. Napoli, ser. 2, vol. x (1901) no. 1.

persistent chimney, in the Phlegrean Fields, on the other hand, a long series of outpourings and explosions took place from many different funnels and vents. It is the object of the present paper to show that in the latter case these phenomena followed a definite order of succession, both in space and in time.

III. THE ERUPTIONS IN THE PHLEGREAN FIELDS.

Taking account of its aspect and its lithological characters, as also of its stratigraphical succession, the eruptive material of the Phlegrean Fields may be divided into three principal categories, which in their turn include evidence of several secondary eruptive phases. The middle division of the three, and the most easily distinguishable, is represented by the well-known characteristic yellow tuff of Posillipo, which forms the main framework of the entire Phlegrean area. The lower division consists of all the various materials which underlie the yellow tuff, and are visible only to a very small extent. Lastly, the upper division comprises all the deposits of later formation than the yellow tuff. This threefold distinction, of petrographical and stratigraphical relations in the series of volcanic rocks in the Phlegrean Fields, points to three main epochs of volcanic activity. It is needless to add that at no single point is the series to be found complete and in the exact order of superposition. Just as the eruptive vents varied in their output, and the subsequent activity of denuding agencies varied also: so too, both in quality and quantity, the representative products of each particular period are seen to be diverse. We may consider, however, that a nearly complete type-section is available in the artesian well of the Royal Garden at Naples, sunk in 1847 at an altitude of 79 feet above sea-level, and going down to a depth of 701½ feet below sea-level, traversing therefore a thickness of 780½ feet of deposits. The section, neglecting minor details, is, in descending order, as follows:—

	<i>Feet.</i>
1. Humus, drift-material, pozzolana, and grey lapilli ...	64
2. Compact yellow and greenish tuff	264
3. Pozzolana, sands, sandy tuffs, pumice, volcanic breccias and conglomerates, intermingled with clays and marls made up also of volcanic constituents of a trachytic facies.....	319
4. Pipernoid grey tuff, similar to that of Sorrento and Caserta	88
5. Pleistocene clayey sands, with marine shells similar to species now living in the Bay of Naples	45½
	<hr/> 780½ <hr/>

Of the formations enumerated in the foregoing section, those included in No. 5 most probably represent the sedimentary platform upon which rest all the eruptive deposits of Campania. The various and complex constituents of 3 and 4 are records of the First eruptive Period, anterior to the yellow tuff. This last, included

under 2, is the representative of the Second Period; and those eruptive materials which are *in situ*, included under 1, mark the Third Period.

We will now examine how the materials belonging to these three successive periods are visibly represented in the Phlegræan Fields.

(1) First Period.

The products of this period may be divided into two great categories, corresponding to two different eruptive phases: the one, more ancient, represented by the well-known piperno and the grey pipernoid tuffs of Campania; the other, made up of alternating beds of pumice, lapilli, sands, breccias, and other volcanic accumulations. It will be well to bear in mind the distinction between these two categories.

(a) Phase of the Piperno and Pipernoid Tuff.

All the broad plain of Campania and all the valleys of the neighbouring calcareous massif of the Apeninnes, from those of Capri and Sorrento to the far-off vales of Salerno, Avellino, Caserta, and Capua, are filled, to a greater or less thickness, with a grey trachytic tuff, in which are scattered small black scoriæ, resembling in appearance the well-known piperno, and consequently termed 'pipernoid tuff.' In its present situation this pipernoid tuff is the outcome of the heaping-up and consolidation, not only of detrital eruptive material, transported by aerial, and perhaps also marine, currents far from the original vents and laid down where it now lies, but likewise of such material as was, both contemporaneously and subsequently, washed down from the mountain-tops by running waters and accumulated in the valleys.

The detrital constituents of which these tuffs are made up (capable of being carried by high winds 30 miles or more away from their original source), must have been so rich in hydrofluoric, hydrochloric, and sulphuric acids, that, helped by the action of percolating waters, they acted upon the limestones against which they rested, and upon such limestone-blocks as were embedded in the tuffs, inducing extreme metamorphism therein, and thus originating the famous fluor-bearing blocks which have been studied by A. Scacchi.¹

These tuffs, as the well-sections and the natural exposures demonstrate, rest almost directly upon the sedimentary rocks of the Campanian basin, and consequently represent the first products of eruption of that part of Campania. They were ejected from volcanoes and craters, which have been completely obliterated by later geological vicissitudes, but must have been at one time concentrated especially in the area of the Phlegræan Fields.

¹ See, in this connexion, Report of the Committee appointed for the Investigation of the Volcanic Phenomena of Vesuvius & its Neighbourhood, drawn up by H. J. Johnston-Lavis, Rep. Brit. Assoc. Adv. Sci. 1890 (Leeds) p. 397. Also W. Deecke 'Zur Geologie von Unteritalien: § 3. Der sogenannte Campanische Tuff' Neues Jahrb. vol. ii (1891) p. 286.

In that area, the work, both destructive and constructive, accomplished by later vulcanicity has been so manifold and extensive, that it is no easy task to trace the equivalent of the pipernoid tuffs. Nevertheless, a great mass of them has been found, as before described, in the artesian well sunk in the Royal Garden at Naples; and less considerable remnants are traceable in the depression that lies between the hills of Vomero and Posillipo. Also at Monte di Cuma, immediately above the great dome of trachyte which forms the base of the historic acropolis, and is perhaps contemporary with the piperno presently to be described.

Instead of the pipernoid tuffs, we find exposed in the Phlegræan Fields as their representative the celebrated piperno. This forms the base of the Hill of the Camaldoli, and, interrupted here and there, by later deposits of yellow tuff and grey pozzolana, may be traced from the spurs of that hill for about a mile and a quarter eastward into the basin of Soccavo, and for other two-thirds of a mile northward into the basin of Pianura, divided into two beds or layers by an intervening band of breccia.

The controversy has been a lengthy one, as to whether the piperno should be regarded as a metamorphosed tuff or as a lava, and even now geologists are by no means unanimous on the point. It appears to the present writer, however, that both the geological conditions and the petrographical characters of the piperno are in favour of the conclusion that it is a trachytic schlieren-lava, the dark stripes of which are made up of such minerals as augite, ægyrine, and magnetite, while the lighter groundmass is of felspathic nature (anorthose), with a spherulitic structure and tiny microliths of ægyrine and augite. It is not claimed, however, that a sharp dividing-line can be drawn between the dark schlieren and the light groundmass.

The occurrence of the piperno at the base of the Hill of the Camaldoli leads to the supposition that this locality, which is practically in the very centre of the Phlegræan Fields, is also the site of one of the principal vents from which was ejected the pipernoid tuff of Campania. This supposition is strengthened by the fact that at that very same spot great explosive eruptions took place at a later period, to which the superposed bands of breccia bear emphatic witness, not to speak of a considerable ejection of yellow tuff. So abundant indeed was the accumulation of eruptive material, that it served to build up the present Hill of the Camaldoli, which, despite successive demolitions and degradations, still forms the most conspicuous elevation in the Phlegræan Fields.

(b) Phase of the Conglomerates and Breccias.

Above the piperno and the pipernoid tuffs comes a succession of strata diverse in character, it is true, but predominantly conglomeratic, and bearing visible traces of the flow of sea-currents and of marine deposition. Whence it may be inferred that, equally

perhaps with the piperno and the pipernoid tuffs, they are the products of submarine eruptions.

The series consists of ashes, sands, lapilli, and trachytic pumice, often intermingled with shell-bearing clays and marls, while intercalated among them and overlying them are conglomerates and coarse breccias of a thickness which varies with their proximity to, or distance from, the vents whence they were erupted. These breccias, to which Dr. Johnston-Lavis has applied the name of Museum Breccias, are made up of blocks of all sizes, torn indiscriminately from the underlying rocks, and therefore of extremely diverse character. Among them may be noticed, as especially abundant, blocks of obsidian, pumice, and scoriaceous trachyte: hardly less numerous are the fragments of leucitic and of metamorphosed calcareous rocks. Taken as a whole, they bear a remarkable resemblance to the breccias of the islands of Procida and Vivara,¹ and date probably from the same period as these.

In fact, we find these deposits of sandy and clayey tuff, of conglomerates and breccias, sometimes intercalated with deposits of rusty-black cinders or scoriæ, most typically developed in that part of the Phlegræan Fields which is nearest the above-mentioned islands—that is, along the entire western base of the Monte di Procida, and on the north-western flanks of the Monte di Cuma. Another remarkable deposit is that which occurs below the Camaldoli, in the shape of picturesque, precipitous, ruddy crags, seen from afar off to be clearly based on the piperno and capped by the yellow tuff. Noteworthy also is the great mass of these strata, about 330 feet of which were pierced through in the artesian boring of the Royal Garden at Naples. Finally, traces of them have been met with below the Vomero Hill, in the course of excavations made for the cable-railway from Montesanto to Vomero.

It need scarcely be added that exactly-similar deposits, overlying the pipernoid tuff, are found in the valleys of Capri, Sorrento, and other localities in Campania. But in this paper we are concerned only with those which lie near their source of origin, in the Phlegræan Fields. Here, indeed, they are exposed only at a few points, being elsewhere mantled over by the eruptive masses of the Second and Third Periods.

(2) Second Period.

Overlying the breccias and conglomerates of the Camaldoli, of Monte di Cuma, and of Monte di Procida, are the masses of the most widespread and most characteristic geological formation to be seen in the Phlegræan Fields—the yellow tuff. This tuff, characterized by a fine cream-coloured or straw-coloured yellow tint, is a well-compacted aggregate of ashes, lapilli, and small pumice-fragments of trachytic nature. Scattered through this uniform matrix are

¹ G. de Lorenzo & C. Riva 'Il Cratere di Vivara nelle Isole Flegree' *Atti R. Accad. Sci. Napoli*, ser. 2, vol. x (1901) no. 8.

fairly-numerous fragments of other tufaceous rocks and lavas, with a few infrequent fragments of felspar and pyroxene-crystals. Among the rock-fragments, the most prevalent is a greenish tuff, very similar to the Epomeo tuff, which has also been met with, in place, below the yellow tuff in the artesian well of the Royal Garden. Trachytic black scoriæ, too, are scattered abundantly through the yellow tuff, diminishing in size as the distance of the exposure from the vents whence they were erupted increases, and being therefore smallest at the outermost periphery of the volcanoes.

The yellow tuff, like similar volcanic deposits, is invariably stratified in very well-marked thin bands, coinciding with the tectonic structure of the volcanic mass of which they form part. This coincidence often helps the observer to reconstruct hypothetically more than one volcanic edifice, which later cataclysms have in part destroyed, or perhaps swept entirely away. The layers, uniformly yellow, are sometimes intercalated with paler grey bands, or, where they have been exposed to surface-alteration, are sometimes covered with a sort of grey film. As a rule, however, the picturesque masses of yellow tuff stand out from afar off, and being fissured by vertical joints, form rugged and precipitous crags, such as may be seen, for instance, below the Camaldoli and at the headland of Posillipo.

The eruptions of ash, lapilli, and pumice whence these masses of yellow tuff, of an average thickness exceeding 300 feet, were derived, were generally of an explosive character. But it seems probable that lava-eruptions, though of rare occurrence, were not entirely wanting; and the products of such outbursts may well be represented by the trachytic masses, met with in the tunnels of the Cuman Railway and of the great Cloaca, which run beneath the Vomero Hill.

These eruptions, like those of the First Period (pipernoid tuff and piperno), must also have taken place under the sea. This may be inferred from the extreme and uniform compactness of the tuff, and from the non-remanié or unaltered shells of *Ostrea*, *Pecten*, and other marine organisms which occur sporadically buried in the tuff.

On account of the great uniformity of this deposit, it does not seem possible to map out any order of succession for the different eruptive vents whence the materials of which it is built up were derived. Geologically speaking, we may regard these eruptions as contemporaneous manifestations of one great phase of vulcanicity which affected the entire area of the Phlegrean Fields.

It is true that some of the volcanoes built up of yellow tuff are better preserved than others, some of which are barely recognizable. But this greater or less degree of preservation is not due so much to difference of age, as to diversity of the accidents to which the volcanoes have been subjected since their formation. Some of them were sooner upheaved above the sea and to a higher altitude, and were consequently exposed to longer and more destructive atmospheric erosion. Several were broken up, or eviscerated, or overwhelmed by later eruptions, while their neighbours escaped.

For these reasons, in the following rapid enumeration of the various volcanoes built up of yellow tuff, it is thought best to adopt a topographical arrangement.

The Volcanoes of Yellow Tuff.

The ashes, lapilli, and pumice of which this tuff is composed, as they were erupted from various orifices scattered about the Phlegræan area, were heaped up around these vents in obedience to the laws of projective energy and gravity, forming therefore so many cones, rather broad and flat than otherwise, with wide and deep craters. In these cones, the material, being uniform in character, accumulated in layers, the major portion of which coincided in inclination with the external slope of the cone; while the remainder was stratified conformably with the internal crater-slope. This structure is in accordance with the law of the formation of detritic volcanoes, whereof Monte Nuovo is a notable example.

After their formation, these cones of yellow tuff, together with the underlying rock-platform, were upheaved above the waves of the sea, and each in turn fell a prey to the destructive agencies of the atmosphere, which proved to be more relentless in their attack at some points than at others. Moreover, within the area of the Phlegræan Fields later vents of eruption opened, (with which I shall deal when describing the Third Period), and by their explosive energy rent and dislocated such of the cones of yellow tuff as lay in their way, and overwhelmed and covered them with fresh erupted material. Thus it is that what we now behold are the mere fragmentary ruins of the volcanoes of yellow tuff, and yet they form the most important and conspicuous feature in the scenery of the Phlegræan Fields.

The southernmost, perhaps, of these volcanoes of yellow tuff still submerged beneath the sea are represented by the two shoals of Mezzogiorno and Penta Palumbo, which, at distances of $1\frac{1}{4}$ and $2\frac{1}{2}$ miles respectively from Cape Miseno, rise from a depth of some 300 feet to within 164 and 98 feet respectively from the surface of the sea, and betray by their conical form their volcanic origin. But we may pass on from these to the consideration of those unmistakable volcanoes which rise above the waves.

First among them is the little Islet of Nisida, which attains a height of 330 feet or so above the sea, while the roots of the volcano certainly go down to at least an equivalent depth below sea-level. The crater, into which the waves flow by a narrow breach open to the south-west, is 360 feet deep, measures 1312 feet round its upper rim, and 490 feet round its lower orifice. These dimensions are almost identical with those of the crater of Monte Nuovo, which it also resembles most strikingly in shape. The typical yellow tuff of which it is built, is unmistakably stratified with a quaquaversal dip along the external slope of the cone and along the inner declivity of the crater. The tuff is crowded with

big black scoriæ, as is always the case in the neighbourhood of the eruptive vents, and is mantled with a thin covering of pozzolana and grey tuff, the products of the later eruptions of the Third Period. The volcano of Nisida, being the smallest and the best preserved of all those that were built up of the yellow tuff, may be regarded as a type and a model for pursuing the study of the remainder.

Practically joined to Nisida by small skerries of yellow tuff, the fine hill of Posillipo towers above the sea with its perpendicular walls some 500 feet high, and its long picturesque summit-ridge stretching inward to Naples. This hill, as has been shown elsewhere,¹ represents the lateral remnants of two contiguous volcanoes, the craters of which opened on the flats of Bagnoli and Fuorigrotta. The western flanks of these volcanoes were demolished by later eruptions (probably from Agnano), while their eastern slopes have survived to form the ridge of Posillipo. In this ridge, the strata of yellow tuff dip outward or towards the south-east. Its crest, like that of every other Phlegrean hill, is crowned with soft grey tuffs and pozzolana, the varyingly-conformable and unconformable superposition of which upon the yellow tuff may be well observed in the great cuttings, and in the caves situated at Piedigrotta and at the outermost extremity of Posillipo, at Coroglio.

Separated from that ridge by a gentle syncline, the hills of the Vomero, Capodimonte, and Poggioreale rise on the north-east: they, too, are fundamentally built up of yellow tuff. The original forms of these volcanoes, however, are not easily made out in this case, as they have been masked by later eruptions and demolitions. It may be that their craters corresponded more or less to the existing curved shores of La Marinella and the Riviera di Chiaja, and that they were divided one from the other by the crest which even now (though in part demolished) projects from the Vomero into the promontory of Ecchia or Pizzofalcone, and thence into the rock-shelves and skerries of Castel dell' Ovo, which likewise consist of yellow tuff. Amid the yellow tuff of the Vomero, the excavations made for the tunnels of the Cuman Railway and for the great storm-water drain, have revealed a considerable mass of trachyte, which bears witness to the probability of lava-eruptions, if not during that period, at least during the immediately preceding age.

The neighbouring Hill of the Camaldoli (1502 feet high), forming the most elevated summit of the Phlegrean Fields, is manifestly made up, for the greater part, of yellow tuff. This is seen on every hand below the loose grey tuffs and the pozzolana, where these rocks have been laid open in the gullies and channels which seam the northern flanks of the hill. The eruptive vents of this yellow tuff were evidently situated in the two basins of Soccavo and Pianura, which preserve to this day an unmistakable crateriform aspect.

¹ G. de Lorenzo & C. Riva, 'Il Cratere di Astroni nei Campi Flegrei' Atti R. Accad. Sci. Napoli, ser. 2, vol. xi (1902) no. 8, p. 72 & fig. 5.

On the other hand, it is no easy matter to trace the original vents or apertures whence were derived the outcrops of yellow tuff which are to be observed around the Piano di Quarto up to its extreme northern boundary (where this is cut by the Via Campana); or those which crop up here and there along the beach from Bagnoli to Pozzuoli. Subsequent geological changes have obliterated every vestige of the original craters.

Between the shore and the Piano di Quarto, however, the volcano of the Gauro, the finest in the Phlegræan Fields, and one of the best-preserved of those built up of the yellow tuff, towers to a height of 1082 feet above the sea. The cone, unbroken on the north, was torn open on the east and west by two subsequent outbursts, and has been worn down on the south by the rains, the winds, and the waves of the sea, which beat against it at the time of its emergence. If we ascend the slopes of this great cone, we see on reaching the summit a vast crater yawning below us (hence the epithet, which Juvenal applied to the mountain, of *Gaurus inanis*), nearly 5000 feet wide and more than 650 feet deep. In dimensions and majesty it challenges comparison with the later, neighbouring crater of Astroni.

Of uncertain origin, again, are the outcrops of yellow tuff which occur along the western portion of the Phlegræan Fields, at Arco Felice, Bacoli, etc. up to the Monte di Cuma, near the so-called Temple of Apollo, and to the Monte di Procida, the eastern shoulder of which is capped by them.

On the other hand, the crateriform character of the Porto di Miseno and Cape Miseno is sufficiently obvious: they are both made up of yellow tuff, overlain by pozzolana and scorïe of later eruption. The crater of Porto Miseno is all but drowned by the sea, its upper rim only emerging in part. Cape Miseno, long famous for its internal structure, laid bare on its broken-down southwestern flank, emerges to the height of 544 feet above the waves, while its roots plunge down to 330 feet below them. Thus, both in dimensions and in form, it is strikingly similar to the crater of Nisida, which may be regarded as the other southern outpost of the Phlegræan Fields.

Moreover, the form of Miseno and Nisida is paralleled by that of Monte Gauro and the other yellow-tuff volcanoes, and this parallelism of form is associated with similarity of structure and petrographic composition. All of which fits in to a certain extent with their common mode of origin, namely, submarine eruptions taking place almost simultaneously over the entire Phlegræan area.

A much greater, though not perhaps an extreme, diversity is found among the later volcanoes, which arose at different points and at different times, and almost all on land in the open air.

(3) Third Period.

It would seem that the eruptions of yellow tuff which had fashioned almost the entire framework of the Phlegræan Fields

were immediately succeeded by an uplift of the whole region, and this by a somewhat lengthy period of erosion; for the later materials are everywhere, not only deposited (sometimes conformably, sometimes unconformably) upon the eroded surface of the yellow tuff, but are evidently derived on the whole from subaërial eruptions.

Thus, we no longer find in these later deposits that uniformity of composition which characterizes the yellow tuff, although they also consist predominantly of fragmental materials of a trachy-andesitic character. They show, however, both macroscopically and microscopically, a certain diversity, according to the particular eruptive vent from which any given material was derived.

Moreover, we are no longer dealing with contemporaneous eruptive vents, scattered, with some approach to regularity, over a vast area, as was the case with the vents whence issued the materials of the yellow tuff; but we can trace a distinct succession, both in time and space, with a progressive limitation and a slow diminution of vulcanicity, all preluding the moribund stage or perhaps final extinction of volcanic activity in the entire Phlegrean area.

In the succession of eruptive vents here, as is the general rule with volcanoes, a primary big vent is followed by one or more of progressively-diminishing size, a diminution accompanied by a slight shifting of the axis of eruptivity. This shifting has been sometimes confined within the circumference of the original crater-rim, and we get as a result a system of concentric craters, or crateri a recinto, as, for example: Agnano—Astroni—and the internal craters of Astroni. At other times, the shifting has been excentric, instead of concentric; and this has resulted in a series of parasitic cones on the outside of the first, as, for example, Astroni—craters of Campana; or Astroni—Cigliano. In other cases, finally, the shifting of the axis of eruptivity has been so considerable, as to leave no point of contact between the new and the old volcano, and to give rise to entirely-different systems, as, for example, Astroni and Monte Nuovo. I propose to enumerate these different volcanic systems of the Third Period, beginning with the oldest and ending with the most recent; and, wherever possible, to show an order of succession between widely-distant and often mutually-independent eruptive vents.

Around each such vent the generally-fragmental material was heaped up in the same manner as that described in connection with the yellow-tuff volcanoes. That is, crateriform girdles were built up, wherein the layers dipped centrifugally outward, and in part centripetally inward. The materials of these cones have a generally greyish tinge, and are much looser in texture than those which constitute the yellow tuff, from which they are therefore easily distinguishable. On the other hand, it is not easy to distinguish, one from the other, the products of the various volcanoes of the Third Period. Consequently, at those localities which are at

some distance from the eruptive vents, and where the material has been spread out and distributed uniformly by the winds and the dynamic force of the outbursts, it is only possible to speak of ashes, lapilli, pumice, and tuffs as promiscuously derived from the central volcanoes. In a few instances only, as, for example, in the case of a small layer of manganiferous purplish ash, which occurs on the summit of the Hill of the Camaldoli and at some other localities in the Phlegræan Fields, can it be said that this particular deposit has been derived from the Astroni eruptions: the evidence for this identification being the existence, in the walls of the Astroni crater, of a thicker band of the same ash.¹ In the same manner, we may conclude that the loosely-textured grey material which almost everywhere caps the hills of yellow tuff (and is known to the quarrymen as *mappamonte*) is no product of disintegration or aqueous erosion, but is on the whole directly derived from the central grey-tuff volcanoes of the Phlegræan Fields.

Not always, however, did the eruptive vents of the Third Period discharge a quantity of material sufficient to build up true crateriform cones, on the type of Agnano, Astroni, Cigliano, Monte Nuovo, etc. Sometimes the outbursts merely rent asunder the ancient deposits of yellow tuff, forming in them 'craters of explosion,' round the rims of which the scanty products of the outburst accumulated. Such are the circular or semicircular cavities which occur dispersedly in the Phlegræan Fields. Thus, from the colossal example of the Piano di Quarto, with a maximum diameter of $2\frac{1}{2}$ miles, we may pass to the Piano di Torre Poerio (north of Astroni and east of the Craters of Campana), to the Piano di Teano (south-west of Monte Gauro), and thence to yet others, until we reach Avernus, the most typical of all these craters of explosion. This too, almost alone among those of the Phlegræan Fields, has furnished, besides the authigenous material erupted from it, scoriæ and blocks of leucotephrite which now form a small band among the layers of fragmental material on its northern flank.

Of course, *pari passu* with the shifting of the axis of eruptivity the craters of accumulation have occasionally alternated with those of explosion. Consequently, if we endeavour to establish a chronological sequence among the central volcanoes of the Phlegræan Fields, we must take account of both categories. A sequence of this kind, as I have said before, can only be determined with a comparative amount of relative certainty. One series, for instance, is exemplified by the contemporaneous craters of Posillipo, Soccavo, or Pianura, with which are successively and concentrically associated the craters of Agnano and Astroni, and the internal cone of the latter.

Another sequence, concentric also, may well be represented by the crater of Pianura, the explosion-crater of Torre Poerio, the

¹ G. de Lorenzo & C. Riva 'Il Cratere di Astroni nei Campi Flegrei' *Atti R. Accad. Sci. Napoli*, ser. 2, vol. xi (1902) no. 8, pp. 22-23.

crater of accumulation of Astroni and its internal cones. A third sequence, in part excentric and in part concentric, is furnished by Monte Gauro, the explosion-crater of Teano, and those of Avernus and Monte Nuovo. Excentric sequences, on the other hand, are exemplified in the crater of Astroni, as well as in the volcanoes of Cigliano and Campana which have arisen on its shoulder; and similarly in the volcano of Monte Gauro, with the subsidiary cones of Concola and Fondo Riccio, which are placed parasitically on its western flanks.

All these concordant sequences demonstrate, not only that eruptive activity was gradually diminishing, but that it was in general contracting towards the centre of the volcanic area; or rather, that it was shifting southward and seaward, receiving from the waters of the ocean the kinetic factor, steam.

But, leaving aside these theoretical considerations, it may be well to describe as briefly as possible the chief among the latest volcanoes of the Phlegrean Fields.

The Volcanoes of Grey Tuff.

The greatest and most ancient of the third series of the volcanoes of the Phlegrean Fields is that of Agnano. Its broad and deep crater, about $1\frac{1}{4}$ miles across, is all but intact on the east, but is partly demolished and partly masked on the west by later outbursts, such as those which have originated the successive volcanoes of Astroni and the Solfatara. The materials of which Agnano is built up, like those of the later volcanoes, consist mainly of layers of pumice, ashes, lapilli, and soft grey tuffs, among which, on the eastern and southern flanks (Monte Spina), are also intercalated beds of scorix. With this volcano we may too, in all probability, associate the great mass of trachy-andesitic lava of Caprara, which, torn asunder and then mantled over by the later eruptions of Astroni, is now involved in the eastern flank of the last-named volcano. From the internal eastern flanks of Agnano thermal mineral springs well forth in great abundance. These are now canalized, and debouch by artificial channels into the sea. But about fifty years ago they united to form at the bottom of the crater a broad and shallow lake, wherein was deposited the detritus carried down from the slopes by rainwash. It was in consequence of the occurrence of these thermal springs, and of the exhalations of steam and gas associated with them, that the ancient Romans created here great baths, which might be successfully restored.

West of Agnano arise the volcanoes of Astroni and the Solfatara, the relative antiquity of which it is at present impossible to determine. The materials of the Solfatara have been completely altered by copious gaseous exhalations. Now, as such altered materials are seen underlying those of Astroni, it may be reasonably argued that the earlier eruptions of the Solfatara were

perhaps anterior in date to those of Astroni. Whereas, however, the great cone of Astroni was thrown up, as it were, with one spurt and finished off in a single gigantic though brief spasm of eruptivity, followed by a few ejections of ashes and scorïæ, and by one scanty outflow of lava in the central portion of the crater: the volcano of Solfatara, on the other hand, remained active throughout a long period, giving rise to small outbursts of lava within the crater itself, and to great trachytic flows which coursed down its southern flanks as far as the sea, there forming the Monte Olibano. In the Middle Ages incandescent lava was still to be seen in the crater of Solfatara, and even at the present day its temperature is higher than that of any other eruptive vent in the Phlegræan Fields. To this long continuance is due the intense alteration, which the gases customarily occurring in fumaroles have induced in the materials of which the volcano is built up, in such wise that it forms an unique instance in the Phlegræan area. The very persistence of this activity, primarily eruptive and subsequently solfataric, leads to the inference that a local magmatic basin, larger than those of the neighbouring vents, exists beneath the Solfatara. This supposition is confirmed by the relatively-greater quantity of lava ejected from this vent than that poured out from the other volcanoes of the Phlegræan Fields, which are, indeed, predominantly built up of fragmental materials. Generally speaking, volcanoes of detritic or of tufaceous type represent the outcome of rapid and violent explosive action, and hence they have a much shorter life than volcanoes of the type which is mainly lavaform or mixed.

On the external north-western slopes of the great crater of Astroni two small adventitious or parasitic volcanoes are to be seen: Cigliano and Campana. The first-named is a simple cone, with a crater eroded on the south by the action of winds and rains upon the friable material of which the cone is wholly built up (ashes and small pumice). The volcano of Campana, on the other hand, belongs to the concentric type (*vulcano a recinto*), being made up of three practically-concentric rings, within the innermost of which is a small but most beautiful crater, rent on the east by a deep and narrow fissure known as *La Senga*. These three 'girdle-craters' of Campana consist of but little ash and lapilli, with a vast mass of scorïæ and bombs, red and black, of trachy-andesitic character, and increasing in quantity inwards in such wise that the latest crater, called the *Fossa Lupara*, may be said to be entirely composed of blocks of lava. It seems probable that the rending-open of the fissure of *La Senga* was brought about by the settling-down and cooling of these blocks.

Of practically the same type as Cigliano, that is, almost wholly built up of ashes and pumice, with a few infrequent scorïæ, is a tiny, barely perceptible *vulcanetto*, known as *Santa Teresa*, which lies on the plain of Bagnoli, south-east of the outer slopes of Agnano. Here, too, as on Cigliano, the rain-laden southerly winds have

broken down and swept away the southern wall of the crater, only the northern part remaining as a crescent-shaped ridge. Little tufaceous hillocks, like that of Santa Teresa, occur at other localities in the Phlegrean Fields, as, for example, the Hill of the Crisci, between Cigliano and Campana. But they have been so greatly denuded that it is no longer possible to determine whether they are the outcome of single eruptive outbursts, or represent remnants left from the erosion of neighbouring craters.

Volcanic deposits of the same type as those of the Campana craters, that is, made up chiefly of red and black scoriæ and bombs, intermingled with fragments of pinkish-yellow tuff, are found dispersedly in the Phlegrean Fields. They invariably overlie the yellow tuff, and underlie the series of grey ashes, lapilli, and tuffs. These deposits are typically massed on the western and northern slopes of the Gauro volcano, forming the so-called Concola and the little volcano of Fondo Riccio. They constitute also the great fan of red and black scoriæ which occurs on the Cleft Mountain or Montagna Spaccata, where the ancient Via Campana runs through a deep cutting into the Piano di Quarto. Again, they are found north-east of the city of Naples, on the eastern slopes of Capodimonte, and at Santa Maria del Pianto and the Ponti Rossi. Yet although, as I have already pointed out, these deposits are lithologically very similar indeed to those of the Campana craters, they must be of much greater age, as is indicated by their structure and by their invariable infraposition below the grey tuff. At La Concola and the Fondo Riccio, the form of the crater from which they were derived may still be traced; on the other hand, not a vestige of it remains among the scoriaceous masses of Santa Maria del Pianto and the Ponti Rossi. The scoriæ of the Montagna Spaccata must have been either contemporaneous with, or of but little later date than, the explosions which gave rise to the great basin that lies east of Monte Gauro, which was possibly anterior to the crater of Astroni and to that of Agnano.

It is no easy matter, however, to determine the precise stratigraphical and chronological relations either of these scoriaceous volcanoes, or of the tuff-volcanoes which range in a direct north-and-south line, west of Monte Gauro and Monte Nuovo, from Monte Ruscello to Bacoli.

The northernmost eminence along this line, Monte Ruscello, is followed southward by a crater-ring known as Monte Grillo, which encircles the later explosive crater of Avernus, this again engirdling Monte Nuovo, the latest volcano of the series and of the entire Phlegrean Fields. South of Baia is yet another little crater of grey tuff, known as Fondi di Baia.

Naturally, the most important of the whole of this series is the crater-lake of Avernus, not only because of its dimensions and depth, but because, alone among the volcanoes of the Phlegrean area, it erupted, besides the customary ashes, lapilli, pumice, scoriæ, and blocks of the underlying yellow tuff, small scoriæ of

leucotephrite, with fine crystals of leucite, which now form a thin stratum in the upper part of the northern flank of the crater. Up to a height of about 130 feet the crater of Avernus is filled with fresh water, which one day perchance percolating below ground fed the thermal springs of Tripergola, and there in September 1538 initiated the outburst of Monte Nuovo. This eruption, with its ejectamenta of ash, lapilli, pumice, and lastly phonolitic scoræ, forms for the present the closing chapter in the history of vulcanicity in the Phlegræan Fields. With a certain amount of hesitation and uncertainty I may, perhaps, venture to summarize that history in the following table:—

SCHEMATIC SYNOPSIS OF VULCANICITY IN THE PHLEGRÆAN FIELDS.

Type of Eruption.	Phases.	Eruptions of ash, lapilli, pumice, and other detritic materials.	Eruptions of lava and scoræ.
Subaerial Eruptions.	Third Period.	Monte Nuovo.	Phonolitic scoræ of Monte Nuovo.
		Fondi di Baia.	Leucotephrite of Avernus.
		Avernus.	
		Monte Grillo.	Lavæ and scoræ of Monte Olibano, of the internal cones of Astroni, and of the craters of Campana.
		Monte Ruscello.	
		Formation of the external girdle of Astroni.	Ancient lavas of the Solfatara. Scoræ of Monte Spina and trachytic mass of Caprara.
		Detritic eruptions of Agnano.	
Submarine Eruptions.	Second Period.	Outbursts of Fuorigrotta, Soccavo, Pianura, Quarto, Teano, etc.	Scoriaceous eruptions of Santa Maria del Pianto, Ponti Rossi.
		Yellow tuff of Nisida, Posillipo, Vomero, Capodimonte, the Camaldoli, Gauro, Pozzuoli, Quarto, Monte di Cuma, Procida, Porto Miseno, Capo Miseno, etc.	(?) Trachytic masses met with in the various tunnels under the Vomero Hill.
	First Period.	Breccias and conglomerates of the Camaldoli, Cuma, Monte di Procida, Monte Santo, etc.	Scoriaceous lavas and scoræ of Monte di Procida, Monte di Cuma, etc.
		Pipernoid tuffs of the Campana.	Piperno. Trachyte of Cuma.

IV. CONCLUSIONS.

We have seen that, in the Bay of Naples, towards the end of the Pliocene and the beginning of the Pleistocene Period, while the Apennine chain was in process of uplift, eruptive phenomena which were then happening beneath the waves of the sea, over an area of local dislocation, laid the foundation of the volcanic districts that now encircle the city of Naples.

In that part of the region which is known as the Phlegræan Fields, we now behold a continuous succession of volcanic formations, the lowermost of which bear unmistakable signs of a submarine origin, while the upper deposits are just as undoubtedly of subaërial origin. The earlier deposits bear witness to phenomena of a more widespread character and of more grandiose dimensions; the later testify to a gradual diminution, both in extent and intensity, of volcanic activity.

The lowermost of these deposits of the Phlegræan Fields are the lavas and pipernoid tufts which may be correlated with the grey tufts that constitute the entire platform of Campania. These are followed by a series of breccias, conglomerates, and layers of scorïæ; and the whole of this earlier submarine series is overlain by the great masses of yellow tuff, which form the framework of all the hills between Naples and Cuma.

The eruption of yellow tuff was followed by an uplift, and by prolonged denudation. Later began a series of subaërial eruptions, the products of which were chiefly ashes, lapilli, and pumice (more or less loosely compacted to form grey tufts), and also a few lavas of trachy-andesitic character.

These subaërial eruptions took place over a more limited area, internal to, and shifted more southward and seaward than, the earlier eruptions. Not only was there this distinction, but the several volcanoes of the second series diminished gradually in intensity and extension, although this diminution was fitful rather than regular. They began with the great outbursts of the enormous ancient crater of Agnano, and died out in the paroxysm of Monte Nuovo.

In this manner the volcanic fires which, towards the beginning of the Pleistocene Period, glowed with such intensity over the entire Phlegræan area, are now confined to a few localities on its southern shore-line; and eruptive energy has shifted its centre a little farther southward, to Vesuvius. Volcanic action, which is always associated with orogenic movements, has in this case also followed upon the uplift of the Apennines: an uplift which, beginning in the north, has been subsequently prolonged and slackened off southward. Thus the subterranean fires which first kindled the volcanoes of the Tuscan Maremma and the Agro Romano, passing on by the Islands to the Phlegræan Fields and Vesuvius, have now travelled farther south, to the flaming Æolian Isles, and snowy Ætna, the pillar of heaven.

EXPLANATION OF PLATES XXVI-XXVIII.

[Altitudes and soundings are expressed in metres.]

PLATE XXVI.

Geological sketch-map of the Bay of Naples, on the scale of 1 : 500,000.

PLATE XXVII.

Sections across the Bay of Naples, on the scale of 1 : 500,000; and sections across the Phlegræan Fields, on the scale of 1 : 100,000.

PLATE XXVIII.

Geological sketch-map of the Phlegræan Fields, on the scale of 1 : 100,000.

DISCUSSION.

The PRESIDENT said that he was glad to find that, owing to the application of modern methods of research, as carried out in this paper, and notwithstanding the increase of our knowledge of vulcanicity derived from such eruptions as those of Krakatoa and Tarawera, these only supplemented and did not supersede the teachings of the classical areas of the Mediterranean, including the Phlegræan Fields. It was a graceful act of the Author to send his paper to the Geological Society of a country, the geologists of which—notably Sir William Hamilton and Sir Charles Lyell—had contributed so much to our knowledge of the Phlegræan Fields.

Sir ARCHIBALD GEIKIE stated that, during the spring of last year, he had had an opportunity of making a number of traverses of the Phlegræan Fields with the Author, and had been so much impressed with the minuteness and breadth of his knowledge of the volcanic history of the district, that he urged him to prepare a succinct statement of this history which could be communicated to the Geological Society. The paper read this evening was the result of this request. It was a grievous loss to science when Prof. Carlo Riva, who had been associated with the Author in the preparation of two admirable detailed memoirs on portions of the Phlegræan Fields, met his tragic death two years ago. But it was hoped that Prof. De Lorenzo would himself continue the work which had been so auspiciously begun. The speaker pointed out the interesting similarity, between the sequence of volcanic events in the Neapolitan, and that in the Roman Campagna. In the latter area, the earliest eruptions, as shown by the remarkable sections laid open by the side of the Tiber to the north of Rome, took place in the Pliocene sea, probably from many submarine vents; while the latest were all subaërial, and piled up the huge cones of the Alban Hill and Bracciano. While rambling over the Roman Campagna, he (the speaker) had not been able to trace out three periods of volcanic activity, and had not found any satisfactory equivalent of the yellow tuff which makes so conspicuous a feature in the Neapolitan region. Two periods of eruption, however, submarine and subaërial, were well-developed, and possibly more detailed investigation and comparison might show the parallelism between the two areas to be even closer than it appeared.