OBSERVATIONS

ON THE

TEMPLE OF SERAPIS

AT

POZZUOLI NEAR NAPLES,

WITH

AN ATTEMPT TO EXPLAIN THE CAUSES OF THE FREQUENT ELEVATION AND DEPRESSION OF LARGE PORTIONS OF THE EARTH'S SURFACE IN REMOTE PERIODS,

AND TO PROVE THAT THOSE CAUSES CONTINUE IN ACTION AT THE PRESENT TIME.

WITH A SUPPLEMENT.

CONJECTURES ON THE PHYSICAL CONDITION OF THE SURFACE OF THE MOON.

BY

CHARLES BABBAGE, Esq.

PRIVATELY PRINTED.

1847.

PRINTED BY RICHARD AND JOHN E. TAYLOR,
RED LION COURT, FLEET STREET.

OBSERVATIONS

ON

THE TEMPLE OF SERAPIS,

AT POZZUOLI, NEAR NAPLES,

WITH

REMARKS ON CERTAIN CAUSES WHICH MAY PRODUCE GEOLOGICAL CYCLES OF GREAT EXTENT.

[Read at the Geological Society of London, March 12, 1834.]

[This paper, by the request of the author, was returned to him soon after it was read, and has been in his possession ever since. Other avocations obliged him to lay it aside, and he only recently returned it to the Council, ready for publication. An abstract both of the facts and of the theory, drawn up by the author, was however printed in the Proceedings of the Geol. Society for March 1834, vol. ii. p. 72.]

THE facts and observations which I have thrown together in the following paper were collected during the month of June 1828, in company with Mr. Head*. They relate to a monument of ancient art, which is perhaps more interesting than any other to the geologist.

I shall first state the facts which came under my own observation, without assuming that they have not been previously noticed, though not aware of their having yet been collected into one point. I shall then suggest an explanation of the singular phænomena which the temple presents, and afterwards briefly sketch those more general views to which I have been led by reflecting on the causes that appear to have produced the alternate subsidence and elevation of the temple of Serapis.

In the year 1749, the upper portions of three marble columns which had been nearly concealed by underwood, were discovered, in the neighbourhood of the town of Pozzuoli. In the following year excavations were made, and ultimately it was found that these columns formed part of a large temple which was supposed to have been dedicated to the god Serapis.

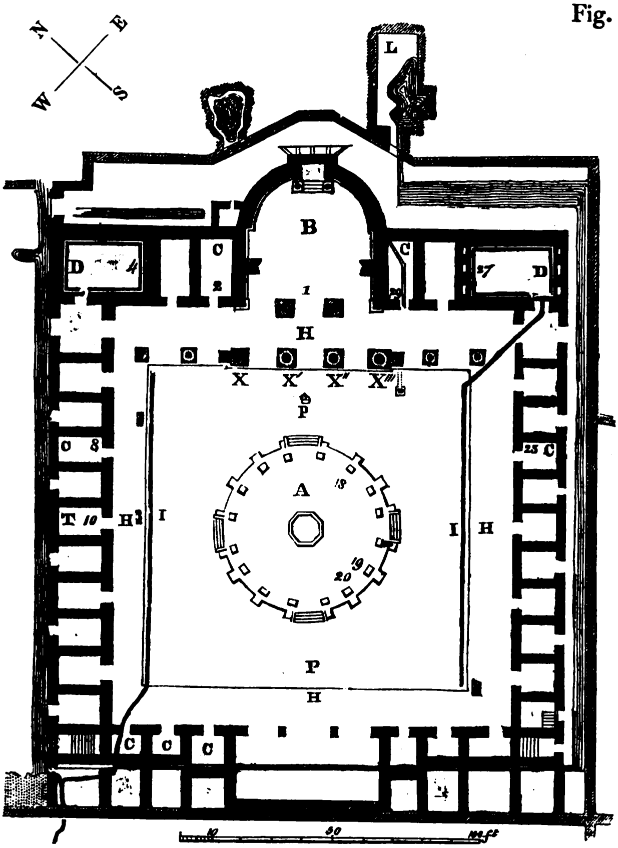
The temple is situated about a hundred feet from the sea, and its form will be better understood from the accompanying view (see Plate I.), taken with a camera lucida, and the ground plan (fig. 1) which is copied from that in the work of the Canonico Jorio.

The most remarkable circumstance which first attracts the attention of the observer is the state of the remaining three large columns, which at present stand in an upright position. Throughout a part of their height, commencing at nearly 11 feet above the floor of the temple, and continuing about 8 feet, they are perforated in all directions by a species of boring marine animal, the *Modiola lithophaga* of Lamarck,—which still exists in the adjacent parts of the Mediterranean.

* Now Sir Edmund Head, Bart.

I shall now give a description of the Temple of Serapis from the notes I made in 1828.

Fig. 1.



1. The external walls of the temple are lowest on the side nearest the sea, where they are about 7 feet 6 inches high. They gradually increase in height, until, at the extreme end of the cella, B, the portion which remains measures 13 feet 4 inches above the pavement of the temple.

2. The three columns X′, X″, X‴, each about 41 feet high and 4 feet 11 inches in diameter at the base, are nearly similar, and are represented in Plate I., X′ being the left-hand column in the plate. The pavement of that part of the temple marked I I, figure 1, is about 5 inches lower than the rest of the internal area.

The top of the base of the shaft is 2 feet 4 inches above the pavement, and the marble of which it is composed is uninjured. That part of the shaft of the column immediately above the base presents nothing remarkable up to the height of 5 feet 8 inches.

3. At this point commences a calcareous coating, which covers the marble for about 1 foot of its height. A space of 1 foot 5 inches follows, which is uncovered and uninjured.

4. It is above this point that the most remarkable phænomena present themselves. The column is here pierced with a number of holes, in many of which are the remains of the Modiola: these remains being firmly fixed in the holes by a dried paste of sandy mud. The attempts of successive visitors have broken most of the shells, and it is difficult, even where the external aperture of the holes admits it, to extract a perfect specimen. Those which are now before the Society were acquired by many hours of labour, during which I first loosened the paste with a steel wire, and then picked out with a pair of tweezers the particles of mud and sand which clogged up the shells. The length, or height, of that part of the column thus perforated is as nearly as I could measure it 8 feet 2½ inches; the lowest perforation being 8 feet 1 inch above the base, and the highest 16 feet 3½ inches above the same level. Near the top of the perforated portion there appears to be a slight indentation quite round the columns, which seems to mark, by the corrosion of the surface, that it remained for a considerable time the line of the level of water.

5. At 6 feet 6 inches above these perforations, the column X″ appears to be cracked nearly through its whole thickness. There are indications of cracks in the two others, but they are more doubtful, and further information on this point is required.

The upper part of this column, about 15 feet 8 inches, is uninjured; its total height above the pavement was found, by measuring with a tape, to be 41 feet 1½ inch, which exceeds the sum of the measures of the separate parts by 4½ inches: the height by the mean of four measures with a box sextant, was 41 feet 4¼ inches.

A number of prostrate fragments of columns are scattered about in the temple. They are of three different sizes, which will be denoted by (1), (2), (3). They are described in the following list.

List of Fragments.

6. A fragment of the upper part of a large column (1) of Cipolino marble, 15 feet long, 13 feet girth. It is perforated in every part, along the whole length and also at the two extremities, one hole of a Modiola being actually in the axis. It is represented in the annexed woodcut (fig. 2.) Serpulæ are attached to this column, and some are found within the holes previously occupied by the Modiolæ.

I extracted from the perforations two complete specimens of an Arca, and also one single valve of the same species of shell. The holes in which these occurred were rather larger than the shells they contained. A thin fragment is split off from one end of this portion of a column.

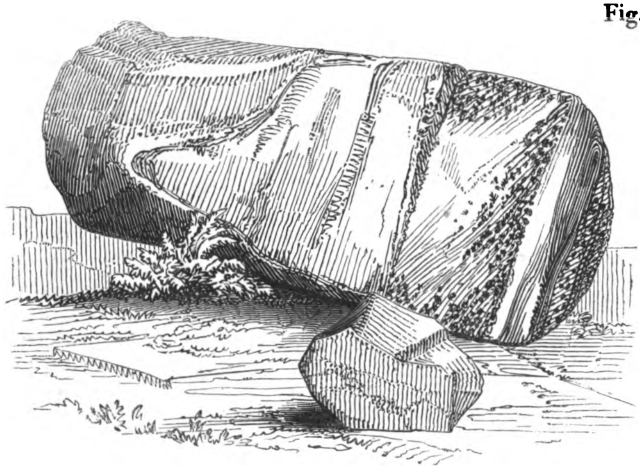
The fragment itself was found at a considerable height above the pavement of the temple, and remained for some time on an elevated bank of sand which the workmen had left. It is so represented in some of the older engravings.

7. A fragment of Cipolino (1), length 10 feet. It is the middle

part of a column. There was a tufaceous deposit remaining attached to it, in which were noticed some very small bits of brick: and a similar deposit covers the broken angles and the ends of the fragment.

There were no marks either of shells or of Serpulæ on this fragment*.

Fig. 2.



8. A fragment of the bottom of a column (1), 17 feet long. The upper edge of the calcareous coating (see par. 3) is 6 feet 4 inches from the base; the breadth of the zone about 1 foot; height to lower edge of disintegrated part of column, 8 feet 7 inches. This fragment is perforated on the upper or broken end almost in the axis, and the disintegrated part also is perforated.

The three preceding fragments appear from their dimensions to have formed parts of one column. Their united length is 42 feet, which is about the height of the columns that remain standing. I did not however record in my notes whether the broken ends favoured this supposition.

9. A fragment (1) 7 feet 4 inches long, perforated at both ends, and all over.

10. A fragment 11 feet 4 inches; from base to beginning of calcareous zone 6 feet 7 inches; breadth of zone 1 foot 4 inches; from base to beginning of disintegration 7 feet 11 inches: not perforated at the base.

11. A fragment (2) of lower portion of a column of African

* The part of the column, which was nearly horizontal, was covered with this deposit to the depth of from a quarter to half an inch, and the rain had washed portions of it away, leaving little miniature columns protected by small caps of stones on their tops. These forcibly reminded me of the clay pillars in the valley of Visp, which I had visited several years before in company with my friend Sir J. Herschel. Several of those pillars were from 50 to 70 feet high, whilst none of these on the fallen fragments of the columns of the temple attained as many hundredths of an inch.

calcareous breccia, length 6 feet 10 inches; from base to beginning of disintegration 4 feet: not perforated at the end.

12. A capital of white marble, perforated; but only four decided marks were observed.

13. A fragment of Cipolino, 9 feet long, the upper end of a column; from the upper end to the beginning of disintegration 7 feet: disintegrated, but not perforated at the fracture.

14. This fragment is half-buried; it is perforated, but not at the end.

15. The lower part of a column (2) of Cipolino, length 12 feet 6 inches; the base is smooth; length from base to top of calcareous zone 3 feet 11 inches; depth of that zone 1 foot; from the top of the zone to the bottom of the disintegration is 7 inches.

16. The lower part of a column of African breccia, length 6 feet 5 inches; it is smooth at the base; from base to upper edge of calcareous zone 3 feet 9 inches; breadth of zone 1 foot 10 inches: not perforated at broken end.

17. Two small fragments; short, and both perforated.

18. A fragment (2) of African breccia, length 8 feet 5 inches, the lower part of a column; from base to top of calcareous zone 2 feet 8 inches; breadth of zone about 1 foot; base to disintegration 4 feet: end not perforated.

19. A fragment, the bottom part of a column (2) of Cipolino, length 9 feet 8 inches; calcareous zone indistinctly marked; from base to disintegration 3 feet 4 inches.

20. A split fragment 7 feet long; it is disintegrated, and has Serpulæ upon it along its whole length, and also at the end.

21. A column of Cipolino, 13 feet 6 inches long; top diameter 1 foot 7 inches; lower diameter 1 foot 10 inches: no perforation or disintegration.

22. A fragment (2) not perforated at the fractures.

23. Fragment of the bottom of a Cipolino column, length 9 feet; from base to disintegration 4 feet 6 inches; zone indistinct; breadth of zone about 1 foot 11 inches; height of top of zone from base 4 feet 2 inches: no deposit on the fractured end; no perforations on the fracture.

24. A fragment of the bottom of a column of African breccia, 12 feet 6 inches long; from base to disintegration 3 feet 8 inches: no calcareous zone; end perforated.

25. A fragment of a granite column, length 7 feet 8 inches; from base to lower edge of zone 4 feet 3 inches; breadth of zone 3 feet.

26. A fragment of a granite column, length 9 feet 2 inches; from base to lower edge of zone 4 feet 3 inches; breadth of zone 3 feet 4 inches.

27. Fragment of granite column, length 11 feet 2 inches; from base to lower edge of zone 4 feet 4 inches; breadth of zone 2 feet 10 inches.

28. Fragment of bottom of a column (2) of Cipolino, 12 feet 9 inches long; from base to disintegration 6 feet 6 inches: not perforated at end.

29. Three fragments perforated.

30. There are two fragments of small entablatures with the holes drilled for working the leaves, but they are not chiselled.

31. An unfinished cornice at the door of T 10, and an unfinished slab at the door of T 5, partly covered with calcareous deposit.

32. A square block, "eaten," (so in Notes, query perforated?).

	ft.	in.
33. The diameter of the large columns is............	4	11
The diameter of the second size................	2	6
Height of the base on which the shafts of the large columns stand..............................	2	4
Height of the base on which the columns in the elevated central part A stand	1	4
Height of elevated central part A above floor of temple..................................	3	7
Step from pavement H down to the pavement I P surrounding the central part.................	0	5

Par. where described.	Material of column.	Portion.	Size of column.	Length of fragment.		Great incrustation. Height of top of calc. zone.		Great incrustation. Breadth of calc. zone.		Height of bottom of decomposing part.		State of fragment.	Position on plan.
				ft.	in.	ft.	in.	ft	in.	ft.	in.		
2, 3, 4	Cipolino ...	entire	(1)....	38	9½	6	8	1	0	8	1	.. ..	1
6	Cipolino ...	top ..	(1)....	15	0	.. ..	..	.. ..	..	.. ..	..	Perforated all over, and at both ends	2
7	Cipolino ...	middle	(1)....	10	0	.. ..	..	.. ..	..	.. ..	..	No perforations...	3
8	Cipolino ...	bottom	(1)....	17	0	6	4	1	0	8	7	Perforated at top, and in axis......	4
9	.. ..	.. ..	(1)....	7	4	.. ..	..	none		.. ..	..	Perforated all over, and at both ends	5
10	.. ..	.. ..	.. ..	11	4	7	11	1	4	7	11	Not perforated at the end.........	6
11	African breccia	bottom	(2)....	6	10	.. ..	..	.. ..	..	4	0	Not perforated at the end.........	7
13	Cipolino ...	top ..	.. ..	9	0	.. ..	..	.. ..	..	7	0	Not perforated at the fracture......	9
14	.. ..	.. ..	.. ..	..	..	.. ..	..	.. ..	..	.. ..	..	Perforated, but not at the end......	10
15	Cipolino ...	bottom	(2)....	12	6	3	11	1	0	5	6	.. ..	11
16	African breccia	bottom	.. ..	6	5	3	9	1	10	.. ..	..	Not perforated at fracture.........	12
17	.. ..	.. ..	2 frags.	short		.. ..	..	.. ..	..	.. ..	..	Perforated........	13
18	African breccia	bottom	(2)....	8	5	2	8	1	0	4	0	End not perforated	14
19	Cipolino ...	bottom	(2)....	9	8	.. ..	..	indist.		3	4	.. ..	15
20	.. ..	.. ..	.. ..	7	0	.. ..	..	.. ..	..	.. ..	..	Serpulæ at end, and on whole length..	16
21	Cipolino ...	.. ..	.. ..	13	6	.. ..	..	.. ..	..	.. ..	..	Not perforated....	17
22	.. ..	.. ..	(2)....	..	..	.. ..	..	.. ..	..	.. ..	..	Not perforated at fractures........	18
23	Cipolino ...	bottom	.. ..	9	0	4	2	1	11	4	6	Perforations--none on fractured end	19
24	African breccia	bottom	.. ..	12	6	.. ..	..	.. ..	..	3	8	End perforated....	20
25	Granite....	bottom	.. ..	7	8	7	3	3	0	.. ..	..	.. ..	21
26	Granite....	bottom	.. ..	9	2	7	7	3	4	.. ..	..	.. ..	22
27	Granite....	bottom	.. ..	11	2	7	2	2	10	.. ..	..	.. ..	23
28	Cipolino ...	bottom	(2)....	12	9	.. ..	..	.. ..	..	6	6	Not perforated at fractures........	24
			3 frags.	..	..	.. ..	..	.. ..	..	.. ..	..	Perforated........	25

Of the Dark Incrustation.

34. On examining the internal walls of the temple, there appears in several of its chambers a dark brown incrustation. Several hori-

zontal lines darker than the rest indicate that this incrustation is a deposit from water, which must have remained in the temple at various heights, from about 2 feet 9 inches to 4 feet 6 inches.

35. The incrustation is of a deep brown colour, varying in thickness from one-sixtieth to about one-twentieth of an inch. It does not adhere very strongly to the walls, which may probably be one reason for the small quantity that remains attached to them. Mr. Faraday, who kindly undertook to examine this, as also the other deposits which will be alluded to, states that "it consists principally of carbonate "of lime; but there is also present a little combustible matter, pretty "universally diffused through the mass; there is also a portion (small) "of peroxide of iron present."

36. The following are my notes made on the spot. The dark incrustation is seen in the chamber marked C 2, fig. 1. It extends over (covers) a piece of marble panelling, and is visible on the walls where there is no panelling. Serpulæ occur upon the incrustation on the marble panelling. Its height from the floor to a dark well-defined line about its middle is 3 feet 6½ inches.

It is again visible in the chamber marked 23 C, but no Serpulæ were observed: height to about its middle 3 feet 4 inches.

In the chamber 29 C, the same deposit is seen extending over the stucco and over the fragments of marble imbedded in it. Its height from the floor to the lower edge is 2 feet 9 inches.

Of the Great Incrustation.

37. At the height of about 9 feet from the floor of the temple a level line runs round several of the chambers, which marks the upper edge of a thick incrustation, evidently deposited from water. The average depth of this incrustation is about 2 feet, but the lower edge, although perfectly well defined, is not a level line; it is in several places slightly inclined and irregular, as it would have been if the lower part of the temple had been filled up with ashes or sand or any other substances. The incrustation covers pieces of wrought marble, African red, &c., and does not fill up certain small holes in the walls but incrusts the inside; also the joints between the marble slabs are indicated by a re-entering in the incrustation.

38. This deposit is visible both on the outside and the inside of the temple. At the north corner, on the outside just beyond the archway, five or six dark lines could be traced on this deposit, as if each had successively been the line of water-level: the moulding of the archway is in many parts covered with this deposit.

In the chamber marked C 8, on the wall as you enter on the right-hand, the upper edge of the deposit is level, but the lower edge inclines towards the centre of the temple.

39. On the inner walls at the south or sea side the deposit is scarcely visible, but it may be seen decidedly to exist in the chambers C to the west of the great entrance. It extends over the marble panelling which remains, as well as over the broken plaster.

It is not visible on the top of the walls on the upper broken edge.

40. The height of the upper edge of this incrustation above the

pavement of the cella B is 9 feet 4 inches, and its average depth about 2 feet.

This incrustation varies in thickness from one-tenth to nearly one-fourth of an inch ; it is hard, and appears to consist of layers deposited in succession, the inner layers being rather more crystalline than the outer.

The exterior surface shows a number of large striæ extending in a vertical direction, and in some parts presents the appearance of being mammellated.

Mr. Faraday informs me that "this deposit consists principally of "carbonate of lime. A little sulphate of lime is present, and also a "little oxide of iron with silica and alumina, but all these together do "not probably make more than four or five per cent. I can find no "magnesia, nor any but the minutest trace of muriates."

Of the Strata in which the Temple was imbedded.

41. At the north corner of the temple on the outside, behind the chamber D 4, I found a good section of the stratified mass by which the temple was covered up. It is about 20 feet high, and I regret that although I measured and noted the thickness of some of the beds, and brought away specimens, yet I did not examine them with that minuteness which my subsequent reasonings upon the facts convince me they well deserve.

No. 1, commencing from the present surface of the adjacent country, is a bed which appears to be a modern accumulation of rubbish. The foundation of a stone wall penetrates this bed, but does not enter the next.

No. 2 is a bed of coarse sand apparently volcanic, and of pebbles mixed with sea shells : it is about 1 foot 3 inches thick, and resembles No. 6, except that it has shells and contains more crystals.

No. 3 is a dark grey sand about 6 inches ; it is almost entirely composed of crystals, and is clearly volcanic.

No. 4 is composed of coarse sand and pebbles, and is about 8 inches thick.

No. 5 is composed of waterworn brick, sea-shells and shingle, and is about 1 foot 8 inches thick. In it occur masses of rolled brickwork, some of them measuring a foot in each direction. Serpulæ are attached to them, and in their interstices shells are found sometimes in good preservation. This bed also contains portions of mosaic.

No. 6, the lowest bed, is probably volcanic tuff. It resembles that compound in colour, and in the roughness and angularity of its aggregated grains ; in the silky pumice-like appearance of some parts, and in containing very minute black grains, possibly hornblende and specular iron. It is pulverulent like that above Pompeii. I did not observe any shells in it, nor are there any indications of its components having been rolled by the sea, although in one part of the section there was an efflorescence of salt.

I believe these beds succeed each other in the order above given, but unfortunately I omitted to measure their height above the pavement of the temple, and I only possess specimens of Nos. 2, 3 and 6.

Various Observations.

42. The water of the Mediterranean enters the temple by a channel of masonry at the west corner, about 3 feet deep and about $1\frac{1}{2}$ foot wide.

At the back of the temple a hot spring L exists. This supplies a bath, which then runs over and mixes with the sea water.

At low water the taste of the water in the channel leading to the sea is that of water impregnated with sulphuretted hydrogen; at high water it is that of weak sea water. Frogs were observed in it.

43. About 5 feet below the pavement of the present temple another was discovered very richly ornamented. This may either have been the floor of a former temple, or the bottom of a bath designedly built below the level of the sea. This latter purpose would however have been attended with this inconvenience, that from the extremely small rise of the tides its water would not have been frequently changed.

44. The circular walls of the inner extremity B are disconnected from those of the temple, as if they had been built at a different period.

45. In the upper part of the north-west wall of the chamber 27 D are parts of three windows, two of which appear to have been repaired. In the centre window is a slab of marble containing an inscription.

A considerable crack extends downwards from another of the windows, and there is another crack at the corresponding window on the right, which extends across the whole floor of the room.

Detached pebbles were found on the top of some of the walls of the temple.

46. The Canonico Jorio remarks that the pavement does not appear to have been broken as if by the fall of heavy bodies; this is generally correct, but the pavement on the step of the sea-side has been removed.

47. The temperature of the bath into which the water from the hot spring (L) flowed was in June 1828—

Bath	99° Fahr.
Air	77
A few days previously I had found	
Water in a vessel in the Grotto del Cane	90° Fahr.
In air	70·5
In grotto of Posilipo	65·5

Facts showing a change of the relative Level of the Land and Sea in the neighbourhood of the Temple of Serapis.

48. About half a mile along the sea-shore towards the west, and standing at some distance from it, in the sea, are the remains of columns and buildings which bear the name of the temples of the Nymphs and of Neptune. See fig. 3, next page.

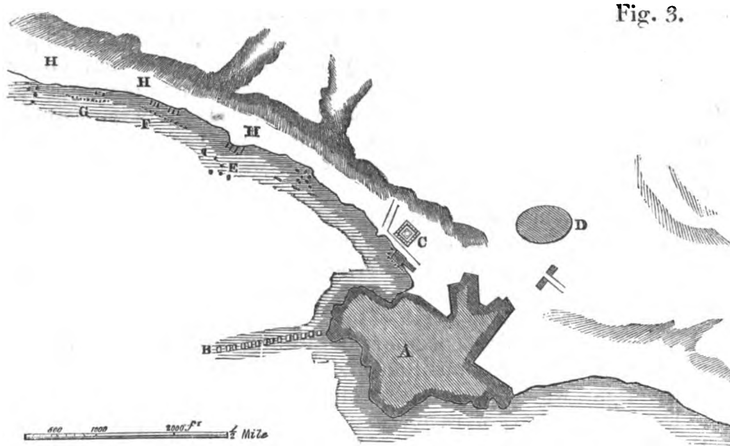
The tops of the broken columns are nearly on a level with the surface of the water, which is about five feet deep.

49. At the east foot of Monte Nuovo an ancient beach may be seen for about fifty yards, which is two feet higher than the present

beach, and which is covered by about seventeen feet of tuff. The part of this older beach which is nearer to Pozzuoli is covered by a stratum consisting of fine sand, shells, and water-worn fragments of brick and pottery.

The whole plain called La Starza, which lies between the inland cliffs and the sea, is of modern formation and consists of beds of pumice or sand, containing recent marine shells, bones of animals and fragments of building not rounded by attrition.

Fig. 3.



A Pozzuoli.
B The Bridge of Caligula.
C The Temple of Serapis.
D The Amphitheatre.
E The Arch of Antoninus Pius.
F The Temple of Neptune.
G The Temple of the Nymphs.
H La Starza.

There are also the remains of two Roman roads, at present under water; one of these reached from Pozzuoli to the Lucrine lake.

50. Another vestige of the art of a remote period which exhibits decided evidence of a change of level, is the series of piers placed in the sea, projecting from the town of Pozzuoli, and known by the name of the bridge of Caligula.

The general depth of the sea around these piers is from thirty-five to fifty feet. There are thirteen piers standing, and two others appear to have been overthrown, as the soundings between the sixth and seventh piers and between the twelfth and thirteenth prove.

51. At the height of about four feet above the present level of the sea on the sixth pier* is a line of perforations, apparently by the Modiola or other boring animal. There are also Serpulæ and other indications of a line of sea-level. I did not find any remains of the shells, and the holes appeared to have been much worn by water.

The depth round this pier, at very small distances from it, was from thirty to fifty feet.

52. On the last pier but one there are great numbers of similar

* I am not quite certain from my notes whether the pier here described is not the fifth, but I am inclined to think not.

perforations, but I did not discover in them any of the shells: there are also adhering to the bricks great quantities of Serpulæ, and something which appeared like a Flustra. I think these holes are incontestably those of some perforating shell, and they reach as high as ten feet above the present level of the sea.*

53. Another instance of alteration of level, although probably of much more ancient date, occurs on the road from Naples to Pozzuoli, near the island of Nisita. The road is cut through a point of rock which projected into the sea. On the inland side a cliff rises, which presents an appearance of a line of sea-level. On examination I found a line containing many perforations, and I extracted from them several casts and bits of shells. One of these is a cast of a species of Lithophagus. After the death of the animal, some small Serpulæ appear to have attached themselves to the inside of its shell, and it was then filled up with tuff. No vestige of the shell remained when I extracted it, but the tufaceous cast is very perfect.

54. In several of these perforations I found casts of a species of Arca; they are small, and do not appear to have been those of the *Arca Noœ*. In one of them I detected a portion of a shell of this genus, which I extracted, and was fortunate enough to find a small fragment which contained the hinge.

Other indications of the former presence of sea-water are the barnacles, which re-appear at intervals adhering to the tuff along this line of perforations.

Inferences from the above facts relative to the Geological History of the Temple.

55. Whether there existed a former temple on the spot occupied by that whose ruins now remain, it is not necessary to discuss.

The rich pavement mentioned (par. 43) as existing five feet below that of the present temple has led to the presumption of a previous building. But if this had existed, the subsidence of the ground on which the old temple stood must have been observed, and would probably have prevented the erection of that with which we are acquainted on the same spot. If this pavement is the remains of a more ancient bath, subsidence previous to the building of the present temple need not necessarily be inferred. Upon this point facts are wanting, and I shall make no conjectures.

There is, *a priori*, considerable probability that a temple, to which were attached a hot spring and baths, was originally built at, or nearly at, the level of the sea, and such I shall presume to have been the case.

* The structure of this pier is curious; it appears to be formed by fragments of stone and brick, connected by a strong cement, and containing within it, near its end, three small piers of brick, from which apparently the arches connecting it with the adjacent piers sprang.

There are also in this pier long cylindrical holes, both vertical and horizontal, about eight inches in diameter. Some of the piers seem to be cased with brick. These remarks, almost accidentally noticed and perhaps not strictly admissible in a geological memoir, are nevertheless added with the hope of inducing those who may have the opportunity, to measure and examine one of the most interesting records of ancient art.

56. Beginning at the floor, the first fact we arrive at in support of this hypothesis is the dark incrustation covering the walls of some of the chambers. It occurs in those marked C 2, 23 C, and 29 C.

Now this incrustation could not have arisen from water confined to these chambers only, because two of them (C 2 and 29 C) are at distant parts of the temple, and the height of the lines of the incrustation are almost the same.

57. Neither could this incrustation have arisen from the water of the hot spring alone, since there are Serpulæ attached to it; unless it be supposed that after its deposit the sea entered the temple, in which case a larger quantity of remains of marine animals ought to have been found.

58. The incrustation could not have arisen from sea-water alone, because the water of the Mediterranean does not, in that neighbourhood at least, leave any such deposit. To prove this, I examined an ancient Roman house in very excellent preservation, which stands partly in the sea in the immediate neighbourhood of Naples, and well deserves more attention than I could bestow upon it. The house consists of three stories and the basement. The walls are remarkably thick, and the different stories separated by arches.

59. The basement stands in the sea and is open to it, and may have been used as a bath, a boat-house, or a reservoir for fish. I entered it in a boat for the purpose of examining the wall, which had probably been exposed to the action of the sea ever since the building of the temple of Serapis; but I found no calcareous deposit, as the portion I have placed on the table will testify.

60. This incrustation must have been formed either before the temple was ruined, or since it was cleared out. We know it has not happened in the latter period.

61. The reason for asserting that it must have occurred previous to the destruction of the temple, is, that there is no indication of any uneven termination at its lower boundary, as there is in the other great incrustation, and as there would have been if the pavement of the temple had been covered with the rubbish caused by its destruction.

62. The conclusion to which these facts point, is, that at some period after the temple had been built, and before it had been much injured, the ground on which it stood gradually and slowly subsided until its pavement became about $4\frac{1}{2}$ feet below the level of the sea.

63. There was probably in ancient times, as there is at present, a channel communicating with the sea; and thus the sea-water which entered became diluted by the water from the hot spring within the temple. Thus the hot spring supplied calcareous matter, and the diluted sea-water was still fit for the existence of the Serpulæ.

64. It has already been remarked, that the lines at the lower edge of this incrustation do not give any indications of an uneven bottom; but as it does not, in the few places where it still remains, extend to the floor of the temple, this fact is not conclusive as to the temple not having been filled up to a certain extent previously to its deposit.

It is however certain that after its deposit, the temple must have been filled up to the depth of from 5 to 9 feet, a fact which is plainly indicated by the form of the lower edge of the great calcareous deposit.

Now the lowest stratum in the section adjacent to the temple, marked No. 6 in Plate II. and described at par. 41, has every appearance of a volcanic tuff: although I did not measure its thickness, I remember it was large compared to most of the others. It probably arose from an eruption of the Solfatara, and falling uniformly over the whole area of the temple, would leave a considerable elevation in the central part, the floor of which was already elevated $3\frac{1}{2}$ feet above the rest of the temple.

If this central part contained, as some have imagined, a circular temple with a marble roof, the weight of 5 or 6 feet of tuff might have broken it down, and thus have caused a still greater elevation in the centre.

65. The next fact given by the observations is the great incrustation. It is much harder and thicker than the preceding, and occurs (see par. 38) behind D 4—in the chamber C 8—in C C, to the west of the great entrance—and also on the standing columns, and on the fragments described in par. 8, 10, 15, 16, 18, 23, 25, 26, 27.

This incrustation cannot have arisen from sea-water, for the reason stated in par. 58. It may have arisen from the hot spring, and this is rendered highly probable from the following fact.

In that singular building called the Piscina mirabile, which is at a considerable distance from the sea, and which is supposed to have been used by the Romans as a reservoir for fresh water, there occurs an incrustation nearly similar in external characters.

Mr. Faraday in speaking of it says, " This is a chemical composi-
" tion as like the last (that of the temple of Serapis) as possible; I do
" not find a word to alter. The state of aggregation is different and
" the successive deposits are not so evident: it is also more cry-
" stalline.

" Your first question, whether the first and second deposits (those
" of Serapis and the Piscina mirabile) are the same substances nearly
" in the same proportion, is already answered in the affirmative. Your
" second, of ' whether the combinations they contain are compatible
" with sea-water, or could they have been deposited in it?' requires a
" little more reservation: I cannot say that the carbonate of lime is
" incompatible with sea-water, or that it could not have been deposited
" from it. But I never heard of such a deposit from sea-water, nor
" can we now-a-days either naturally, or during the evaporation which
" goes on in salt-works, &c. &c. On the other hand, they represent
" perfectly such deposits as are taking place continually from waters
" holding carbonate of lime in solution by carbonic acid, and I cannot
" help thinking that such has been their source. In giving this opinion
" I am guided merely by the appearances of the deposits and their
" chemical characters, for I know nothing of the circumstances under
" which they occur, although twenty years ago I happened for a few
" hours to be at the temple of Serapis."

66. It should be noticed, that the portion of the incrustations attached to the standing columns and to the fallen fragments, although the same in chemical composition, is not quite so hard, and is in a different state of aggregation from that on the walls; also that no remains of Serpulæ or other sea shells have been noticed on it. The upper edge of this incrustation is level; the lower edge is irregular, as it would have been if the bottom of the temple had been filled up.

67. The conclusion from these facts is, that after the temple had subsided to a small extent its whole area was filled, either from a shower of volcanic ashes, or from some other cause, up to a certain height, apparently leaving the centre most filled up—that the same cause probably closed up the channel communicating with the sea—that in consequence of this, the water from the hot spring, having no outlet, filled the temple to such a height, that the waste from leakage and evaporation equalled the supply.

68. Admitting this explanation, the temple could have suffered little from decay previously to this event. Some of the marble panelling may have fallen down, as one of the specimens seems to prove. But the greater part of the columns must have been standing, because their fragments are surrounded by zones of various breadths arising from this incrustation.

69. From considering this fact, we are enabled to restore many of them to the positions which they must have occupied. Thus the fragment described in par. 8, and marked (4) on the plan and in the table, must have been a portion of one of the large columns standing on its base during the period this incrustation was forming, because—

	ft.	in.
Height of top of incrustation on column	6	4
Height to the base of the shaft of the large column	2	4
	8	8

The sum of these gives very nearly the average height of the top of this incrustation above the pavement of the temple, which was about 8 feet 10 inches or 9 feet.

70. Again, if we extract from the synopsis the two instances in which the lower portions of smaller Cipolino columns have marks of incrustation, we find from—

	ft.	in.
No. 15	3	11
No. 23	4	2
Average	4	$0\frac{1}{2}$
Add to this, height of the base, from No. 33	1	4
Height of central part of temple, from No. 33	3	7
	8	$11\frac{1}{2}$

which is nearly the height of the great incrustation.

71. Again, the granite columns give the following height of the incrustation:—

	ft.	in.
From No. 25	7	3
From No. 26	7	7
From No. 27	7	2
Mean height	7	4
Add height of base	1	4
Height of great incrustation	8	8

These columns therefore could not have stood in the central elevated part of the area of the temple, because in that case the incrustation must then have been 3 feet 7 inches lower down on them.

72. If we compare in the same way the two portions of the columns of African breccia, we find—

	ft.	in.
No. 16, height of top incrustation	3	9
No. 18, height of top incrustation	2	8

Now the difference of 1 foot 1 inch in the height of the water-line is too large to attribute to any uncertainty in the measures, and leads me to believe that I must have entered in my note-book by mistake the word 'top' instead of 'bottom' of incrustation, when recording the fragment described in No. 18. If this were the case, then, adding the breadth of the incrustation which is 1 foot, we have for the top of it 3 feet 8 inches, which I shall adopt.

	ft.	in.
Hence No. 16, height of incrustation	3	9
No. 18, height of incrustation	3	8
Mean height	3	8½
Height of base	1	4
Height of elevated central part of the temple	3	7
	8	7½

which again is nearly the height of the top of the incrustation. It is however known that the columns of African breccia were part of the central temple.

73. There is, however, one circumstance which requires an explanation. The fragment described in par. 7 is covered with a calcareous deposit of the same nature as that which we are considering. It is the middle portion of a large Cipolino column, of which No. 8 is the base and No. 6 the top.

Now since the middle portion must have fallen into the lake formed by the hot spring (for it is incrusted all over), it is natural to inquire, why the top portion has escaped that fate, and is found perforated in all directions by the Modiolæ? The solution of this difficulty seems to be, that the top portion of the column fell on a part of the filling up of the temple which was above the reach of the lake formed by the hot spring, whilst the middle portion fell nearer the base of the column and into the lake; consequently, when the lake was filled up this fragment was covered up, and when the whole subsided into the sea, the part on the higher ground became immersed and perforated all over.

The fragment (par. 15) must have been standing on the central or elevated part of the temple when the great incrustation was formed, because—

	ft.	in.
Height of top of deposit from base..........	3	11
Height of base..........................	1	4
Height of central part of temple............	3	7
	8	10

which is the height of the great deposit. On the other hand, its top reaches 7 feet above the lowest perforations of the Modiolæ; for—

	ft.	in.
Height of fragment	12	6
Height of its base	1	4
Height of central part of temple	3	7
Height of fragment above floor of temple when standing..	17	5
Lowest perforation..............................	10	4
	7	1

It would appear, since 7 feet 1 inch of the height of this column must have been under water, that its upper part ought to have been perforated, which was not the case. It follows, therefore, either that, prior to the subsidence below the level of the sea, this central part of the temple was filled up to the depth of nearly 18 feet, whilst the surrounding part was not filled above 11 feet—an improbable supposition—or that after the great incrustation the temple must have been overthrown prior to its subsidence, and probably before the second filling up.

74. This is further confirmed by the fragment described in par. 24, which is of the same length. Being of African breccia it must have stood on the central part, and its top must have been at the same height above the floor of the temple as that of par. 15. It *is* perforated, and at the broken end, and therefore could *not* have been wholly covered up prior to the subsidence of the temple into the sea.

If it had been thrown down after that event, the whole length would have been perforated, which was not the case.

75. The next fact which presents itself is an appearance of disintegration on ten of the columns or fragments, which is not always accompanied with perforations of the Modiolæ. Whether this arose from a shower of hot ashes or from the subsequent irruption of the sea, or whether there are sufficient indications of its existence as distinct from the perforations, is perhaps still a matter of some doubt.

76. The next fact which presents itself in ascending from the floor of the temple, is the existence, in the three columns that remain standing, of the remarkable perforations which have fixed the attention of naturalists and geologists.

The Modiolæ which perforate rocks live at various depths below the surface of the sea, and although there are instances of marine animals inhabiting a mixture of sea- and fresh-water, yet they are comparatively rare. In the present instance we find three genera, which are very numerous—the Modiolæ, the Arcæ, which seem to have sheltered themselves in the untenanted abodes of the former genus, and the Serpulæ, which attached themselves to the inside of the shells of the Modiolæ, or to the sides of the cavities made by them.

77. The facts which have been adduced (par. 48 *et seq.*) to prove a subsidence of the adjacent land are conclusive upon that point, and concur with the section immediately behind the temple, to show that at one period its pavement must have been considerably below the Mediterranean. But that section cannot be adduced as an argument, until we have refuted a theory which has been offered to explain the history of this temple, without having recourse to subsidence and elevation.

It has been supposed that a great storm which partially destroyed the temple threw up a bar between it and the sea, and filled the area with sea-water containing the young of the several marine shell-fish which are found in the columns.

The objections to this theory are—1st, that it supposes a salt lagoon to have existed for many years in a hot climate, with its surface 9 feet above the level of the adjacent sea, and without any supply of water; when evaporation must soon have dried it up, and the water from the hot spring could not have supplied it, without leaving traces of another incrustation similar to those described as the dark deposit and the great incrustation; 2ndly, that the supposed lagoon must have existed in a cavity in a porous sandy soil, as is proved by the section close to the temple (par. 41)—and yet that a pressure of 9 feet of water did not cause such a reservoir to leak.

If it be urged that a lake has already been supposed to have existed in a former state of the temple, and that these objections are equally fatal to that lake, the answer is, that in the former instance there was a constant supply of water from the hot spring to replace the loss by evaporation and leakage—that the depth of this lake was much less—and that the deposit of carbonate of lime from the hot spring might have contributed to render its sandy bottom less pervious to water.

Either of these objections is fatal to the lagoon theory. When it is added, that this hypothesis is insufficient to explain the first incrustations without new suppositions—that it does not remove the necessity for a subsidence of the ground, which it was invented to supersede—that there are clear and unequivocal proofs of such changes of level in the immediate neighbourhood of the temple, and that the section close to it concurs in proving that the ground on which it stands was subject to those changes—it is quite unphilosophical to admit an hypothesis supported by no fact, and refuted by many.

It would seem then that the temple subsided into the sea; but whether this happened slowly, or at intervals by repeated shocks of earthquakes, does not appear. Nearly at its lowest point there are indications of its having been stationary. For about 6 inches below the highest perforation of the Modiolæ the columns are corroded, as if that point had remained exposed for some time, alternately to the action of wind and water.

78. The next period in the history of the temple was its gradual re-elevation. Whether the deposit out of which it was dug covered it up before or after this event, is not perhaps distinctly evident. From the section behind the temple, I am induced to suppose that it preceded the elevation; and the chance of the columns not being overthrown by any sudden rising, would be considerably increased by the support they would derive from having more than one-half their height imbedded in earth.

79. The preceding conclusions involve no hypothetical agents, and may be considered as inferences fairly resulting from the specimens collected, from the facts observed on the spot, and from the historical evidence of changes, which have actually happened in the neighbourhood of the temple. I shall now proceed to offer some conjectures relative to the causes of the successive changes in the level of the ground on which this temple stands—conjectures which I wish to be considered as entirely distinct from the former part of this communication.

79*. On examining the country round Pozzuoli it is difficult to avoid the conclusion, that the action of heat is in some way or other the cause of the phænomena of the change of level of the temple. Its own hot spring, its immediate contiguity to the Solfatara, its nearness to the Monte Nuovo, the hot spring at the Baths of Nero on the opposite side of the bay of Baiæ, the boiling springs and ancient volcanos of Ischia on one side and Vesuvius on the other, are the most prominent of a multitude of facts which point to that conclusion.

The mode by which this heat operates is a question of greater difficulty, and in the absence of sufficient data, it may be enough to point out shortly some of its possible results.

80. It may be imagined that at a considerable depth below the surface a vast reservoir of melted lava exists, containing highly elastic matter imprisoned within it by the pressure of the superincumbent strata. The addition of matter supplying this elastic fluid, or the accession of heat, may increase the expansive force;—or on the other hand, the expansion or contraction of some portion of the superior strata may cause a fissure through which the melted lava may be forced up by the elastic fluid. In such circumstances, besides the earthquakes which will be caused by the rent, and the stream of lava which issues through it, the whole of the strata resting on the fluid lava will slowly subside. The cooling of the lava may then fill up the rent and the strata again rise as before, until a renewal of the same cause reproduces a renewal of the same effect. It may here be remarked, that the expulsion of the immense quantity of gaseous matter, which some volcanos are known to throw out, may lower the temperature of the cauldron below, more effectually than the abstraction of the lava which is ejected from it.

81. Another view of the subject is, that there may exist below the ground in the neighbourhood of Pozzuoli cavities containing water or other condensed gases in a highly heated state; and that any accession or diminution of heat, arising from the volcanic causes in operation

in the neighbourhood, will increase or diminish the elasticity of these gases, and thus cause an elevation or subsidence in the strata above.

82. A different view however of the effect of heat may be taken, one which refers to causes well known to exist, and the effects of which have in some instances been measured. The solid beds below the temple are themselves liable to expand by the action of heat, and to contract by its abstraction; rents and earthquakes, as well as elevations and depressions of the surface, may be the result of the partial operation of this cause. Let us inquire whether sufficient effect can arise in this way, without imagining masses of immense thickness to have altered their temperature; a change which might have required longer time for its completion than the phænomena admit.

From a series of experiments upon the expansion of various stones by the application of heat, made by Mr. H. C. Bartlett, of the U. S. Engineers, under the direction of Col. Totten, and recorded in the American Journal of Science, vol. xxii. p. 136, it appears that for 1° of Fahrenheit's scale*—

"Granite" expands	·000004825
"Marble"........................	·000005668
"Sandstone".....................	·000009532

From these data I have calculated the expansion of those substances for various degrees of temperature, and for thicknesses varying from 1 to 500 miles. The table is given in the Appendix. From this it may be inferred, that if the strata below the temple and its immediate neighbourhood are equally expansible with sandstone, a change of temperature of only 100° F. acting on a thickness of five miles would cause a change of level of above twenty-five feet—an alteration greater than any of the observed facts at the temple of Serapis require.

A similar change would be produced by supposing the temperature of a bed one mile thick raised 500° F.; and if the temperature of a bed of such matter 2600 feet thick were raised 1000°, its surface would be elevated by twenty-five feet.

The difficulties of this theory are, that some part of the surface at the piers of Caligula's Bridge is at present raised above its former level, and other parts, as the temple of the Nymphs and of Nep-

* Other experiments have since been made by Mr. Adie, of which an account is given in vol. xiii. of the Trans. of the R. Soc. of Edinburgh. From this the following list of expansions are extracted:—

	Expands.
Roman Cement, per 1° Fahr.	·00000750
Sicilian White Marble..................................	·00000613
Carrara Marble	·00000363
Sandstone from Craigleith Quarry....................	·00000652
Slate from Penrhyn, Wales..............................	·00000576
Peterhead Red Granite	·00000498
Arbroath Pavement	·00000499
Caithness Pavement	·00000497
Greenstone from Ratho..................................	·00000449
Aberdeen Grey Granite	·00000438
Best Stock Brick..	·00000306
Fire Brick..	·00000274
Black Marble, Galway....................................	·00000247

tune, are still below that level; whilst the temple of Serapis appears to have returned nearly to its former state. The answer to this is, that the thickness of the expanding beds may differ in different parts, or may have a different power of conducting heat—or it may be remarked, if the conducting power and the thickness be the same, that the distance from the source of heat may be different, and consequently the full effects may have reached the piers of the bridge, and yet not have attained the other points.

Another objection to our hypothesis is, that the columns of the temple are nearly vertical*, whilst the inclination of the strata, as proved by the perforations in the 6th and 12th piers of the bridge, shows an inclination which would be sensible. To this it may be replied, that during the transit of the wave of heat through the strata under the temple, the columns may have been slightly inclined and yet have retained their position, even if they had not been supported by being imbedded in the tuff and sand which then filled the temple. Or it may happen that the beds on which the temple stands are separated by faults or rents from their continuation under the other buildings; and if they be thus isolated, the effect of heating and cooling them would be to raise and lower the temple in a vertical position.

On the whole this explanation is the most tenable, because it is founded on facts—viz. that matter expands by heating; that great accessions of heat have at various times taken place in the neighbourhood of the temple; that it is sufficient to account for the phænomena by supposing a moderate depth of the beds below it heated to a degree which it is not unreasonable to presume must have taken place; that such changes of level would on the whole occur gradually, although they might be accompanied with earthquakes and occasionally by sudden changes of level—facts of which we have historical evidence as having happened on this spot.

83. In reflecting on the preceding explanation of the causes which produced the changes of level of the ground in the neighbourhood of Pozzuoli, I was led to consider whether they might not be extended to other instances, and whether there are not still other natural causes, constantly exerting their influence, which, concurring with the known properties of matter, must necessarily produce those alterations of sea and land, those elevations of continents and mountains, and those vast cycles of which geology gives such incontrovertible proofs.

84. The small depth at which melted lava may exist below the surface of bad conductors of heat, had forcibly struck me in an expedition I made to Vesuvius during the interval between my visits to the temple of Serapis. Having descended into the great crater of Vesuvius to examine a little crater within it, which was then in a state of activity, throwing up pumice occasionally from 300 to 600 feet high, I was desirous of ascertaining the depth of the great crater. Accordingly, having taken the angles of certain points and measured, on the rough lava plain at its bottom, a base of 330 feet, I left a walking-stick fixed upright to mark its termination. After

* The late Capt. Basil Hall subsequently ascertained, by comparing these columns with their image reflected in the water, that they are very sensibly out of the perpendicular.

taking the angles at the opposite end I remeasured the base, and found it 331 feet; but on returning the walking-stick was in flames. In many of the crevices a foot or two in depth, the lava was red-hot. The bottom of the small crater in which the pasty semi-fluid lava was tossed about, was, I should think from memory, not more than fifty feet below the spot on which I stood. The depth of the plain at the bottom of the crater below the lowest part of its upper edge was, on the 3rd June 1828, about 505 feet.

I had been surprised at the small distance (two or three feet only) which separated the red-hot lava from the less heated surface on which I had been walking, and had carried on my trigonometrical operations, without experiencing much inconvenience from the heat. The view of the melted lava had however disappointed my expectations: instead of possessing fluidity, it ought rather to be described as a pasty viscous mass, having some degree of toughness, of an uneven surface, occasionally pushed up by a force from below which caused elevations that very slowly subsided, or more frequently were removed or interfered with by succeeding efforts of the same force.

85. The following explanation of the origin of the changes which have continually taken place in the forms and the levels of large portions of the earth's surface at many distant periods of time, and which appear still to continue their slow but certain progress, arose from the examination of the temple of Serapis, which has been detailed in the former part of this paper.

The theory rests upon the following principles:—

1st. That as we descend below the surface of the earth at any point, the temperature increases.

2nd. That solid rocks expand by being heated, but that clay and some other substances contract under the same circumstances.

3rd. That different rocks and strata conduct heat differently.

4th. That the earth radiates heat differently from different parts of its surface, according as it is covered with forests, with mountains, with deserts, or with water.

5th. That existing atmospheric agents and other causes are constantly changing the condition of the earth's surface, and that, assisted by the force of gravity, there is a continual transport of matter from a higher to a lower level.

The existence of the four latter causes has long been fully admitted: the only one on which any uncertainty rests is the first. All measures which have been made of the increase of the earth's heat as we descend below its surface concur in pointing out the fact, although, as might be expected, almost every case gives a different amount of descent for an elevation of temperature of one degree of Fahrenheit. In tracing out some of the consequences which necessarily result from the continued action of these five causes, it will be necessary to assume the truth of the first, although it is not necessary that we be acquainted with the law of its variation; nor is it absolutely essential that we should suppose the heat to increase to such an extent, as to render the whole of the central parts of the earth fluid.

86. If we imagine at every point of the earth's surface a line drawn to its centre, then if a point be taken in any one line at a

given temperature, there will be contiguous points of exactly the same temperature in all the adjacent lines; and if we conceive a surface to pass through all these points, it will constitute a surface of uniform temperature, or an isothermal surface. This therefore will not be parallel to that of the earth, but will be irregular, descending more towards the centre of the earth, where it passes under deep oceans.

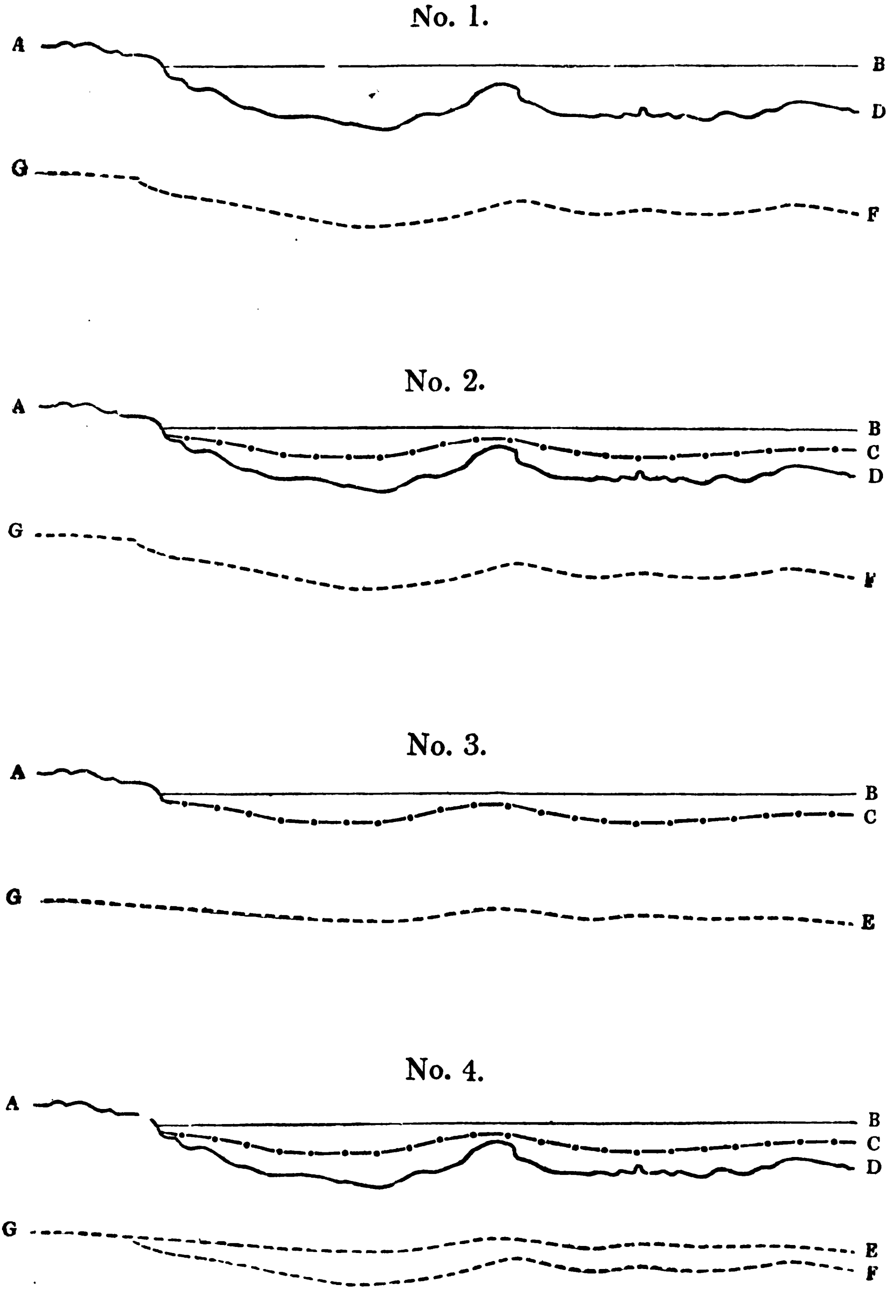
An increase of 1° of Fahrenheit's thermometer, for every fifty or sixty feet we penetrate below the earth's surface, seems nearly the average result of observations. If the rate continue, it is obvious that, at a small distance below the surface, we shall arrive at a heat which will keep all the substances with which we are acquainted in a state of fusion. Without however assuming the fluidity of the *central* nucleus—a question yet unsettled, and which rests on very inferior evidence* to that by which the principles here employed are supported—we may yet arrive at important conclusions; and these may be applied to the case of central fluidity, according to the opinions of the several inquirers.

87. If we consider the temperature of any point—for example, G, situated two miles below the surface of an elevated table-land A, in the annexed woodcut fig. 4; and if we imagine a surface passing through all the points of equal temperature within the globe, then, as this surface passes under the adjacent ocean, which we may suppose, on an average, to be two miles deep, it is evident that the *surface of equal heat* will descend towards the earth's centre; because, if it did not, we should have great heat nearly in contact with the bottom of the sea. In number one, B is the surface of the ocean; A D the surface of the land, and of the bed of the ocean. The broken line G F is the isothermal line. Let us now suppose, by the continual wearing down of the continents and islands adjoining the ocean, that it becomes nearly filled up. The broken line C, in number two of the woodcut, indicates the new bottom. The former bottom of the ocean being now covered with a bad conductor of heat, instead of with a fluid which rapidly conveyed it away, the surface of uniform temperature will rise slowly but considerably, as is shown at G E, in number three. In number four, the first bed of the ocean A D, and its isothermal line G F, as well as the new bed, A C, of the ocean, and its corresponding isothermal line G E, are all shown at one view.

88. The newly-formed strata will be consolidated by the application of heat; they may, perhaps, contract in bulk, and thus give space for new deposits, which will, in their turn, become similarly consolidated. But the surface of uniform temperature below the bed of the ocean, cannot rise towards the earth's surface, without an increase in the temperature of all the beds of various rock on which it rests; and this increase must take place for a considerable depth. The consequence will be a gradual rise of the ancient bed of the ocean, and of all the deposits newly formed upon it. The shallowness of this altered ocean will, by exposing it to greater evaporation from the effect of the sun's heat, give increased force to the atmo-

* The reader will find this question fully discussed in the 32nd and 33rd chapters of Lyell's Principles of Geology, 7th edit.

Fig. 4.



N.B.—These woodcuts are stereotypes from *one* block, in the manner described p. 266, Ninth Bridgewater Treatise.

spheric causes still operating upon the inequalities of the solid surface, and tend more rapidly to fill up the depressions.

89. Possibly the conducting power of the heated rocks may be so slow, that its total effect may not be produced for centuries after the sea has given place to dry land; and we can conceive in such circumstances, the force of the sun's rays from without, and the increasing heat from below, so consolidating the surface, that the land may again descend below the level of the adjacent seas, even though its first bottom is still subject to the elevatory process. Thus, a series of shallow seas or large lakes might be formed; and these processes might even be repeated several times, before the full effect of the expansion from below had permanently raised the whole newly-formed land above the influence of the adjacent seas.

If the whole sea, or particular portions of it, were originally much deeper, as, for instance, ten or twenty miles, then a portion of the solid matter beneath its surface might, after a lapse of many ages, acquire a red, or even a melting heat, and the conversion into gases of some of the substances thus operated upon might give rise to earthquakes, or to subterranean volcanos.

90. On the other hand, as the high land gradually wears away by the removal of a portion of its thickness, and as the cooling down of its surface takes place, its contraction might give place to enormous rents. If these cracks penetrate to any great reservoirs of melted matter, such as appear to subsist beneath volcanos, then they will be compressed by the contraction, and the melted matter will rise and fill the cracks, which, when cooled down, become dykes. Rents therefore or veins may arise by contraction from cooling, and proceed from the surface downwards; or they may result from expansive forces acting from below and proceed upwards.

If these rents do not reach the internal reservoir of melted matter, and if there exist in the neighbourhood any volcanic vents connected with it, the contraction of the upper strata may give rise to volcanic eruptions through those vents, which might be driven by such a force almost to any height. These eruptions may themselves diminish the heat of the beds immediately above the melting cauldron from which they arise; for the conversion of some of the fluid substances into gases, on the removal of the enormous pressure, will rapidly abstract heat from the melted mass.

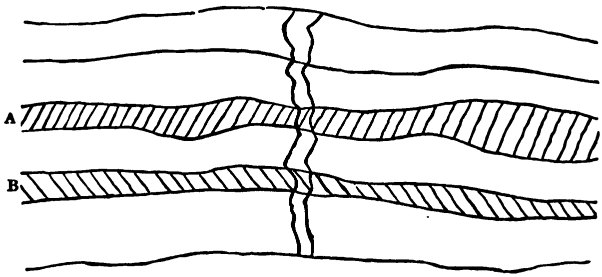
As the removal of the upper surface of the high land will diminish its resistance to fracture, so the altered pressure arising from the removal of that weight, and its transfer to the bottom of the ocean, may determine the exit of the melted matter at the nearest points of weakest resistance.

91. Other consequences might arise from the different fusibility of the various strata deposited in the bed of the ocean. Let us imagine in the next woodcut (fig. 5), the two beds A and B to melt at a much lower temperature than those between which they intervene. It might happen, by the gradual rising of the isothermal surfaces, that one or both of these strata should be melted; and thus, supposing all the beds originally to have contained marine remains, we might, at a distant period, discover two interposed beds, without any trace

of such remains, but presenting all the appearances of former fusion, resting on, separated by, and existing under, other beds of demonstrably marine formation.

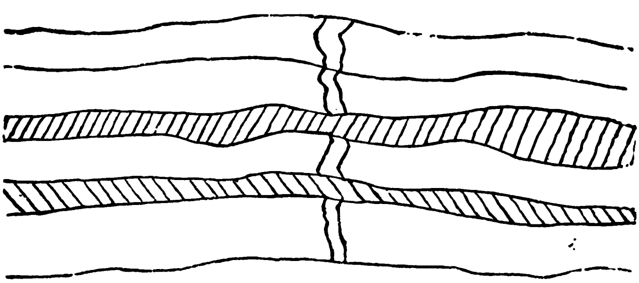
If, during that former state of fusion, rents should have been formed through several of the strata, injection of the liquid matter might proceed from these melted beds, both upwards and down-

Fig. 5.



wards. If, on the contrary, older dykes had penetrated all the strata, it is possible to suppose such a degree of fusibility in the older dyke, or such chemical relation to the melted bed, that the portions of the dyke passing through that bed should be obliterated, whilst those that traverse the less fusible beds, protected from such action, should remain unaltered, as in the annexed cut (fig. 6).

Fig. 6.



92. Another consequence of this constant change in the position of the isothermal surfaces must be the development of thermo-electricity, which, acting on an immense scale, may determine the melting of some beds, or the combination of the melted masses of others, or cause the segregation of veins and crystals, in heated though not fluid portions of the strata exposed to its influence. Nor may the dykes themselves be without their use, either in keeping up the communication for the passage of electricity, if they are good conductors; or in separating the groups of strata which produce it, if they are bad conductors.

93. It is by no means necessary that these fused strata should be

connected by dykes or other means with any cauldron of melted matter below; nor even that any large portion of the interior of the earth should be in a melted state. The mere advance of the isothermal surfaces may cause some more readily fusible strata to melt between its two adjacent more refractory companions. Two beds even—such, for example, as compact fluor and sulphate of lime—may each, when separated by intervening beds, have been submitted, by the passage of a highly heated isothermal surface, to intense heat without fusion: yet two exactly similar beds occurring higher up in the series, and perhaps not submitted to the same intense heat, may, if placed in immediate contact, by acting on each other as fluxes, become for ages a liquid fiery ocean, intercalated between strata regularly deposited from water.

94. The effects of this fusion of some intermediate strata may also be to alter the surface and dislocate all the beds above. If the matter expand by fusion, then elevations and cracks will ensue: if it contract into smaller compass on melting, then subsidences will occur; and in both cases, when a large extent of the earth's surface rests on a fluid bed contained in an irregular cavity, we may expect, from the difference of the weight above it at different points, that a system of irregular elevations and depressions will continue for a time to occur, until the conditions of equilibrium are fulfilled between the superincumbent weight and the fluid or semi-fluid and viscous mass.

This process will require time for its completion, and when accomplished, the surface above will remain undisturbed for ages.

It appears also that in case the intervening melted strata contract, the surface of the country above may be influenced by two or more causes. First, by the general elevation arising from the expansion of all the solid strata by heat, arising from the advance of the isothermal surface towards the surface of the earth. Secondly, by the depression arising from the melting of one or more of the intermediate beds. The joint action of these causes may produce many successive alternations of elevation and depression in the same portion of the earth's surface.

95. For the elucidation of this subject, it appears very important that experiments should be made on the effects of long-continued artificial heat in altering and obliterating the traces of organic remains existing in known rocks. It seems probable that, by a well-planned series of such experiments, we might be enabled to trace the gradually disappearing structure of animal remains existing in rocks subjected to fire, into marks which, without such aid, seem utterly distinct from that origin; and that we might thus establish new alphabets with which to attempt the deciphering of some of the older rocks*.

96. It appears, therefore, that from changes continually going on, by the destruction of forests, the filling up of seas, and the wearing

* Some experiments, with this object in view, were undertaken at the recommendation of the British Association (see Third Report, p. 479, and Fourth Report, p. 576), and portions of rock containing organic remains have already (1838) been exposed, for above five years, to the heat of the hearth of a blast furnace, at the Elsecar Iron Works in Yorkshire, through the permission of Earl Fitzwilliam, and at the Low Moor Works, by that of the proprietors.

down of elevated lands, the heat radiated from the earth's surface varies considerably at different periods. In consequence of this variation, and also in consequence of the covering up of the bottoms of seas, by the detritus of the land, the *surfaces of equal temperature* within the earth are continually changing their form, and exposing thick beds near the exterior to alterations of temperature. The expansion and contraction of these strata, and, in some cases, their becoming fluid, may form rents and veins, produce earthquakes, determine volcanic eruptions, elevate continents, and possibly raise mountain chains.

The further consequences resulting from the working out of this theory would fill a volume, rather than a memoir. It may however be remarked, that whilst the principles on which it is founded are really existing causes, yet that the sufficiency of the theory for explaining all the phænomena can only be admitted when it shall have been shown that their power is fully adequate to produce all the observed effects.

Addition in 1847.

It appears from the preceding paper, that the joint action of certain existing and admitted causes must necessarily produce on the earth's surface a continual but usually slow change in the relative levels of the land and the water. Large tracts of its surface must be slowly subsiding through ages, whilst other portions must be rising irregularly at various rates: some, though perhaps few, may remain stationary.

It is a curious and an interesting fact, that this geological deduction, derived from pure reasoning, although suggested by the observations made on the temple of Serapis, which was first published in 1834, should soon after have received direct confirmation from an entirely opposite quarter.

Mr. Darwin, whose voyages and travels extended from 1826 to 1836, was gradually accumulating and arranging an immense collection of facts relating to the formation of coral and lagoon islands, as well as to the relative changes of level of land and water. In 1838 Mr. Darwin published his views on those subjects, from which, amongst several other very important inferences, it resulted, that he had, from a large induction of facts, arrived at exactly the same conclusion as that which it has been the chief object of this paper to account for, from the action of known and existing causes.

The Cav. Antonio Niccolini published at Naples in 1839 a valuable series of observations of the low-water mark of the Mediterranean in the Temple of Serapis. It results from his reduction of these observations, that during each year there has been a small, though not a uniform, depression of the level of the temple below the sea.

Mr. Smith (of Jordan Hill) has, in a paper recently read before the Geological Society, given the following results of his inquiries, which with his permission I append:—

Observer.	Year.	Height of high water above floor of temple in inches.
Smith (Jordan Hill)	1819	0
Forbes	1826	12
Babbage	1828	14
Niccolini	1838	20
Forbes	1843	26
Smith	1845	28

Mr. Smith found the floor of the temple dry at high water in 1819, and twenty-eight inches on it at high water in 1845. At low water in the latter year the floor was covered by eighteen inches of water.

APPENDIX.

No. 1. *Periods in the history of the Temple, founded on observation, or inferred from Geological and Physical evidences.*

1. Ancient mosaic pavement constructed 5 feet below the floor of the temple. (See Section at A, and Par. 43, 55.)

2. Dark incrustation, round the walls, formed previous to any filling up of the temple, which was then filled to the depth of about three or four feet with a mixture of fresh and salt water. (Par. 34, 35, 36, and 56 to 64.)

3. First filling up of the temple to the height of about 7 feet above the floor. (Section between floor and line E E, Par. 64, 67.)

4. Period during which the great calcareous deposit was forming in the freshwater lake made by the hot spring. (In Section deposit is shaded: Par. 3, 37 to 40, 65, 66.)

5. Partial destruction of the temple. (Par. 64.)

6. Corrosion round several of the columns just above the calcareous deposit. (Par. 75.)

7. Second filling up to the height of about 10½ feet. (Section between E E and G G.)

8. Further destruction of the temple and subsidence below the level of the sea: perforations in the columns. (Par. 4, 76.)

9. Third filling up to the height of from 20 to 35 feet above the floor of the temple. (Section between G G and I I, Par. 78.)

10. Re-elevation of the temple above the present level of the sea. (Par. 78.)

11. Excavation of the temple in 1750.

12. Gradual subsidence of the temple between 1828 and 1845. (See *Addition in* 1847.)

No. 2. *Dates of Historical facts connected with the Temple of Serapis.*

	B.C.
1. Colonization of Puteoli, according to Livy, lib. xxxiv. 24	194
2. Lex Parietis faciendi	105
	A.D.
3. Eruption of Vesuvius, destruction of Pompeii and Herculaneum	79
4. Probable time of construction of the temples whose remains now exist, toward the end of the 2nd century.	
5. Eruption of Vesuvius	203
6. The temple adorned with precious marbles by Septimius Severus............................ between 194 and	211
7. The temple adorned with precious marbles by Alexander Severus .... between 222 and	235
8. Valerius Maximus states that a bank was begun and finished, on the right side of the market, by throwing things into the sea, on account of the incursion of the storm......	230
9. Pozzuoli ruined by Alaric........................	456
10. Eruption of Vesuvius........................	472
11. ————	542
12. Pozzuoli ruined by Genseric	545
13. Eruption of Vesuvius	685
14. Pozzuoli ruined by Romualdo II. Duke of Benevento..	715
15. Eruption of Vesuvius	993
16. ————	1036
17. ————	1043
18. ————	1138
19. ————	1139
20. Eruption of Solfatara........................	1198
21. Monte Epomeo, Ischia, active........................	1302
22. Eruption of Vesuvius	1306
23. Earthquake........................	1488
24. Eruption of Vesuvius........................	1500
25. Grant to the University of Pozzuoli of the land drying up from the sea (La Starza: see H H, fig. 3, page 12)	1503
26. Grant to the city of ground dried up (desiccatum) ..	1511
27. Monte Nuovo, Eruption of........................	1538
28. Eruption of Vesuvius	1631
29. ————	1660
30. ————	1682
31. ————	1692
32. ————	1701
33. ————	1704
34. ————	1712
35. ————	1717
36. ————	1730
37. ————	1737
38. Temple of Serapis dug out........................	1750
39. Eruption of Vesuvius	1751
40. ————	1754

No. 3. *Table showing the Expansion, in feet and decimal parts, of Granite from* 1 *to* 500 *miles thick, for various additions of temperature.*

Miles in thickness.	Degree of Fahrenheit's Scale.							
	1.	20.	50.	100.	200.	500.	1000.	3000.
1	·0255	·510	1·275	2·55	5·10	12·75	25·5	76·5
5	·1274	2·548	6·370	12·74	25·48	63·70	127·4	382·2
10	·2548	5·096	12·740	25·48	50·96	127·40	254·8	764·4
15	·3821	6·642	19·105	38·21	76·42	191·05	382·1	1146·3
20	·5095	10·190	25·475	50·95	101·90	254·75	509·5	1528·5
25	·6369	12·738	31·845	63·69	127·38	318·45	636·9	1910·7
30	·7642	15·286	38·215	76·43	152·86	382·15	764·3	2292·9
35	·8917	17·834	44·585	89·17	178·34	445·85	891·7	2675·1
40	1·0190	20·380	50·950	101·90	203·80	509·50	1019·0	3057·0
45	1·1464	22·928	57·320	114·64	229·28	573·20	1146·4	3439·2
50	1·2738	25·476	63·690	127·38	254·76	636·90	1273·8	3821·4
55	1·4012	28·024	70·060	140·12	280·24	700·60	1401·2	4203·6
60	1·5286	30·572	76·430	152·86	305·72	764·30	1528·6	4585·8
65	1·6559	33·118	82·795	165·59	331·18	827·95	1655·9	4967·7
70	1·7833	35·666	89·165	178·33	356·66	891·65	1783·3	5349·9
75	1·9107	38·214	95·535	191·07	382·14	955·35	1910·7	5732·1
80	2·0381	40·762	101·905	203·81	407·62	1019·05	2038·1	6114·3
85	2·1655	43·310	108·275	216·55	433·10	1082·75	2165·5	6496·5
90	2·2928	45·856	114·640	229·28	458·56	1146·40	2292·8	6878·4
100	2·5476	50·952	127·380	254·76	509·52	1273·80	2547·6	7642·8
200	5·0952	101·904	254·760	509·52	1019·04	2547·60	5095·2	15285·6
500	12·7380	254·760	636·900	1273·80	2547·60	6369·00	12738·0	38214·0

In order to employ this table for the expansion of marble under the same circumstances, increase the number found by the above table one-sixth. To find the expansion of sandstone, double the number found in the table for granite.

This table was computed by the Difference Engine from the first line, which was of course taken from experiment.

It will be observed that the numbers are always true to the last figure, a compensation made by the engine itself. As however the machine had not then been taught to print its computations, the accuracy of the table can only possess that of careful printing.

No. 4. *List of Shells determined by Professor E. Forbes.*

From below the Tuff of Monte Nuovo.

	Range in fathoms.	Remark.
Spondylus gadæropus	½—14.	The presence of the Haliotis along with Arca barbata and the Spondylus, indicates that these shells were imbedded *on a coast-line at water mark.* The others were washed up.
Arca barbata	0—4.	
Cardita sulcata	2—30.	
Venus verrucosa	0—40.	
Modiola tulipa	2—50.	
Haliotis lamellosa	littoral.	
Shells in cavities of the columns.		
Lithodomus lithophagus	littoral.	Indicate coast-line at water-mark *with certainty.*
Arca barbata	littoral—4.	
Vermetus sublamellatus?	littoral.	
Shells from holes in Tuff, 38 *feet above the Mediterranean.*		
Arca lactea	0—great depth.	Indicate a coast-line at water-mark.
—— barbata	littoral—4.	
Cast of Lithodomus	littoral.	
Shells from Strata near the Temple of Serapis.		
Conus mediterraneus	littoral—10.	The whole assemblage in this case indicates the line of water-mark, most of the species being such as live there, only mingled with those living immediately below it and washed up.
Bulla striata	under 1 fathom.	
Patella bonnardi	littoral.	
Fissurella neglecta	littoral.	
Trochus umbilicaris?	sublittoral.	
Scalaria lamellosa	near coast-line?	
Cerithium furcatum	littoral.	
—— vulgatum	5—40.	
Columbella rustica	0—55.	
Nassa variabilis	0—27.	
Vermetus gigas	sublittoral.	
Arca lactea	0—very deep.	
—— Noæ	littoral and deep.	
—— barbata	littoral.	
Cardita sulcata	7—30.	
—— trapezia	0—95.	
Chama gryphoides	0—50.	
Lucina divaricata	?	
—— pecten	0—16.	
Venus fragilis	littoral.	
—— aurea	littoral—10.	
—— geographica	5—15.	
—— verrucosa	littoral—40.	
Mesodesma donacella	littoral.	

No. 5. *Description of the Plates.*

Plate I.— *View of the Temple of Serapis.*

I am indebted to the kindness of Mr Edward I'Anson, Jun., for this excellent representation of the temple. It was taken by means of the Camera Lucida in 1836, and may, I believe, be relied upon even to the minutest details.

Plate II.—*Section of the Temple of Serapis, showing the changes it has undergone.*

I constructed this section from a series of measures made at the temple in June 1828, in company with my friend Mr. Head. Several days were occupied, and some important questions were discussed on the spot. Mr. Head also entered into the antiquarian questions, which, if they had been admissible into these transactions, would have added greatly to the interest of the story of the temple of Serapis.

	Paragraphs where referred to.
A At bottom on right-hand, pavement of ancient temple	43, 55
BB Line of low water of the Mediterranean, June 1828	
CC Line of high water ditto	
DD Level of the top of mixed sea and fresh-water lake	34, 35, 36
Dark deposit below that line..................	56 to 64
EE Irregular line representing the first filling up of the temple....................................	64, 67
This filling up reaches from the bottom to EE.	
FF Level of the top of fresh-water lake	37, 64
GG Irregular line of second filling up. The other boundary of this filling up is EE.	
HH Highest level attained by the sea	77
I I Irregular surface of the soil out of which the temple was dug in 1750.	

I I and GG are the two boundaries of the third filling up.

The sketch of the bank and wall M on the left side is accurate where measures are given, but in other respects it must not be considered as rigidly correct.

P.S.—It may be interesting to state, that very recently (1847), in the operation of boring for an Artesian well at Venice, four different beds of peat were passed through at the respective depths of 29, 48, 85 and 126 metres. It is thus proved, that at four different epochs, the surface, which appears to have been slowly subsiding, was covered with freshwater lakes of small depth.

(M. De Chablaye Sur les Forages Artésiens Pratiqués à Venise. Comptes Rendus de l'Académie des Sciences, 2 Aug. 1847, p. 214.)

SUPPLEMENT.

CONJECTURES CONCERNING THE PHYSICAL CONDITION OF THE SURFACE OF THE MOON.

The perusal of Mr. Darwin's explanation of the formation of coral reefs and of lagoon islands led me to compare these islands with those conical crater-shaped mountains which cover the moon's surface; and it appears to me that no more suitable place could be found for throwing out the following conjectures, than the close of a paper in which I have endeavoured to show, that known and existing causes lead necessarily to results analogous to those which Mr. Darwin has so well observed and recorded.

These islands, described by Mr. Darwin, consist of a very narrow slip of coral margin surrounding a lagoon, often of considerable depth, and sometimes having one or more islands within it.

It has been ascertained that the animals which build coral reefs do not exist at a greater depth than from twenty-five to thirty fathoms: and hence the difficulty of accounting for lagoon islands, which, formed entirely of coral, rise at once almost precipitously from an unfathomed ocean.

Mr. Darwin's explanation of their peculiar structure is, that the bases of the islands were originally the elevated points of a shallow sea in which the corals flourished;—that the bottom of this sea subsiding very slowly, the animals successively perished, and new generations built their habitations on the calcareous remains of their progenitors.

The coral of which these islands are chiefly formed, flourishes most in situations most exposed to the action of breakers. The perpetual change of the water thus brought into contact with them probably supplies them with more food than they could obtain in quieter situations, and may account for their more luxuriant growth. The exterior line or coast of small coral islands which have reached the surface of a shallow sea will therefore increase more rapidly than the interior, to which the water has less easy access. And as these islands slowly descend by the subsidence of the bottom on which they rest, the exterior reef effectually deprives the whole of the corals in the interior of their most nourishing food; the still water of the lagoon soon ceases to produce the hardier coral, and species of more delicate form and of much slower growth are always found to occupy the central lagoon.

If we imagine a sea containing a multitude of such lagoon islands to be laid dry, the appearance it would present to a spectator at the moon would strongly resemble that of a country thickly studded with volcanic mountains, having craters of various sizes. May not therefore much of the apparently volcanic aspect of the moon arise from some cause which has laid dry the bottom of a former ocean on its surface?

If such an ocean were deserted by its water, these lofty crater-shaped peaks would present to the distant spectator the appearance of volcanic craters from which streams of lava have issued. The vast size of the supposed craters on the moon's surface is not alone sufficient to refute such an hypothesis; for one of the lagoon islands mentioned by Mr. Darwin is ninety miles across. Neither is the great length of the bright streams radiating from those craters an objection; for, in consequence of the force of gravity towards the moon being only one-sixth of what it is on the earth's surface, sediment even of the same density as chalk would travel six times as far before reaching the bottom of a lunar ocean.

It is now well ascertained by observations that certain varieties of chalk consist almost entirely of microscopic shells, of several species of small corallines, and of the remains of infusoria. It has also been shown by Lieut. Nelson that the deposit in the lagoons of coral islands consists of a very fine white sediment, much resembling soft chalk in composition, and not distinguishable from it in appearance. It is also known that there is frequently an opening in the leeward side of lagoon islands.

By combining these facts it seems probable, that in consequence of the action of the tides and of the breakers on the windward side dashing over into the lagoon, there must frequently arise a current from the lake into the ocean, which will of course carry with it the chalky sediment from within. As the surrounding sea is of great depth, this fine sediment will be carried to a very considerable distance before it reaches the bottom, and thus may form long lines of a white deposit, varying in shape according to the nature of the currents by which it is conveyed*.

* The distribution of triturated substances over large surfaces, whether conveyed by water, by air, or by any other fluid, depends on—

1. The specific gravity of the substance.
2. The shape of its particles.
3. The resistance of the fluid to its motion.

If there is no fluid to obstruct the fall of the powdered substance, the shape of its particles is immaterial. It will continue to descend according to the law of gravity with a continually accelerating velocity.

But when such particles fall through a resisting medium, they soon reach a *terminal velocity*, at which, the force of gravity exactly balancing the resistance of the medium, no cause is in action to alter the uniformity of their descent.

If the fine particles present a large surface in proportion to their weight, and if their centre of gravity is so placed as to compel them to fall in the direction of their greatest resistance, they may descend with so small a velocity as to be carried to vast distances even in a subtle fluid like air, and scarcely any limit need be assigned to their migrations in denser fluids.

A familiar instance of this occurs in an amusement of which children are fre-

It may be added, that in several instances the appearances explained by the imagined superposition of two craters might also be explained on the supposition of their arising from causes similar to those which on the earth's surface produce parallel roads or terraces; namely, altered lines of water-level. Amongst others, the spots marked in Madeler's map Tycho, *a b c* Heinsius, Abulfeda, and Lindenau, offer resemblances to circular parallel roads, which might however have been made by an alteration of the level of a fiery fluid, as well as by that of an alteration through the agency of water.

The view above presented respecting the crater-shaped elevations on the moon's surface requires that we should account for the removal of that ocean in which it has been hazarded as a conjecture that they may have been formed.

Sir John Herschel has remarked, that it is "extremely singular in "the geology of the moon, that although nothing having the cha-"racter of seas can be traced, (for the dusky spots which are com-"monly called seas, when closely examined, present appearances in-"compatible with the supposition of deep water,) yet there are large "regions perfectly level, and apparently of a decided alluvial cha-"racter*."

An essential element in such an inquiry is the question of the existence of water, or of other fluids, on the moon's surface, and the consequences which would result from the truth of that hypothesis.

The projection of a large mass of matter from that side of the moon which is for ever invisible to the inhabitants of the earth, may have left a cavity sufficiently large to have drained off the ancient ocean. Or vast and profound rents may have been formed on the moon's surface by volcanic force, or by contractions arising from its cooling, into which the sea may have retired. Or if atmospheric agencies are at work, the same processes of elevation and subsidence must be taking place as on the earth's surface, as has been already explained in the paper on the Temple of Serapis.

It is usually stated that the moon has no atmosphere. The non-existence of any clouds above its surface is adduced as a proof, as well as the absence of any effect of an atmosphere in the occultation of stars by that body.

This latter argument is of much weight, since the change in form of a planet occulted by the moon would become perceptible with an amount of atmosphere corresponding to a very small pressure of the barometer. The consequent absence of water on its surface has also been inferred: but these inferences are not entirely satisfactory, although they lead towards the conclusion, that if the moon really

quently fond. They connect by small pieces of thread the four corners of a square sheet of thin paper, with a small bit of cork suspended below it. On loosing this parachute from the upper window of a house, in consequence of its shape and small weight, and of the position of its centre of gravity, it is borne along by the wind to great distances before it finally reaches the earth.

* Cabinet Cyclopædia, Astronomy, p. 229.

have an atmosphere, it must either possess a very small refractive power, or be insignificant in amount.

If the moon have no atmosphere there can be no winds, and consequently no conveyance of volcanic ashes to great distances by their means. Under such circumstances, whenever the volcanic action is perpendicular to the surface, as is nearly always the case, all the projected matter will fall back immediately into their craters, or at all events will constitute cones around them. The steepness of such cones will depend on the nature of the materials of which they are composed.

Even in the case of any oblique jet of volcanic ashes on the moon's surface, supposing it without an atmosphere, they could not be carried far unless by an exertion of enormous force, and in that case they would be shot out in a parabola, and would descend continuously in the same spot, and form a cone of ashes at a distance from its original source, and scarcely connected with it by any visible traces. If indeed the projecting force were to commence or to diminish slowly, a train of ashes more or less distinct, according to the time during which the increase or decrease of the force acted, might become visible; but in all cases this line would be a straight one, unless the position of the mouth changed.

On the other hand, it is very difficult to admit that innumerable volcanos should cover the moon's surface, without supposing the occurrence of the circumstances usually concomitant with them on the earth, one of which is the eruption of vast quantities of gases. If such eruptions have occurred, they must during a succession of ages have supplied an atmosphere to the moon, unless its surface presented matter which would absorb or chemically combine with the gases thus produced.

Again, the entire absence of all effects of the moon's atmosphere on the fixed stars must be questionable until the singular fact of the occasional appearance of a star *upon and within* the moon's disc for several seconds previous to occultation is explained on independent grounds.

The absence of clouds on the moon can be affirmed only of that portion of it which is presented towards the earth, and which is also illuminated. The heat of the sun acting on one-half of its surface with great intensity during fourteen of our days might readily be supposed to dissipate any clouds on the illuminated part, the vapour from which would condense on the cold or unilluminated hemisphere which is invisible to us.

During fourteen of our days and nights, each portion of the moon's surface is successively exposed at different angles to the action of the sun's rays. The degree of heat communicated to it depends on several causes, which it may be expedient to state and to consider.

The supply of heat from the sun is itself in some measure variable in a small degree by its obscuration by spots, but chiefly by its greater or less distance from the moon. In consequence of the time of the moon's rotation on its axis being equal to that in its orbit round the earth, the hemisphere which is visible to us will be unremittingly exposed to the sun's rays whilst it is traversing that part of its orbit which is most distant from the great source of heat.

That hemisphere on the contrary which is never turned to the earth, will be exposed to the sun's rays during the half of the moon's course in which it is nearest to the sun. Thus, supposing all other circumstances equal, the portion of the moon's surface presented towards the earth will always be less heated by the sun than its opposite hemisphere. The radiation from the earth may possibly in a certain degree alter this difference.

The surface of the moon itself may reflect more or less of this heat. Judging from that surface with which we are acquainted, and supposing it to reflect heat in nearly the same proportion as it does light, we should admit that the greater part of the heat from the sun is absorbed by the moon's surface. Its invisible hemisphere is probably similarly constituted; but of this we are not certain.

If the surface of the moon reflects much of the heat which arrives at it from the sun, it will absorb little. If it reflects little of that heat, it will absorb the rest.

It is well known that a thermometer whose bulb is blackened and placed within a cavity of charcoal or of blackened cork, and covered with a plate of glass, will, when exposed to the sun's rays, rise rapidy, and reach a temperature above even that of the boiling point. The shallow pools of water left by the receding tide on grassy meadows adjacent to a river, acquire under much less favourable circumstances a considerable temperature. In both these cases the heat readily penetrates the respective surfaces, and being then altered in its character, passes much less freely back in the opposite direction. The bad conductors, cork, charcoal, grass and earth, prevent its transmission onwards, and consequently the intermediate air and water become excessively hot.

The following observations recently published are extracted from those made by Sir John Herschel at the Cape of Good Hope. They show how much the temperature of bodies exposed to the effect of solar heat depends upon the conditions under which they are acted upon. They also illustrate the principle, that radiant solar heat, after passing through glass and acting on solid bodies, becomes nearly incapable of being radiated back through the glass which it had just passed.

It is on this principle that greenhouses act as traps for catching and imprisoning the sun's rays: probably some very slight difference in the composition of the glass of which they consist may considerably alter this power. It has long been remarked in Belgium, that glass of a green tint is favourable to the warmth of a greenhouse. If the solids or the fluids on the surface, or if the atmospheres of distant planets possess the properties of reflection, radiation and absorption in certain degrees, it is by no means impossible that some of the most remote of them may be hotter than those which are much nearer to the central body.

"1837.		Fahr.
30 Oct. $2^h\ 51^m$.	Thermometer just immersed in a heap of earth cast up by ants, and quite dry	° 125
	In a convex heap of sandy soil, in a small garden enclosure sheltered from wind, and moist at three or four inches below the surface	143
	In contact with a stem of *Albuca viridiflora* in flower, at half an inch below the surface	120
7 Nov. 2 23.	Temperature of a heap of garden mould just below the surface	155
	Under the still green leaf of *Brunswickia multiflora*	96
	In contact with the stem of a tuberous Pelargonium in full flower, just below the surface	131
	Inserted an inch into the moist and decaying crown of *Hæmanthus Tigrinus* losing its leaves	102
24 Nov. 1 45.	Temperature of a heap of garden-mould	145·5
1 Dec. 0 36.	In a sand-heap sheltered from wind, in the small garden enclosure above-mentioned	162

3 Dec.	Therm. in sun $2\frac{1}{2}$ inches above a hard trodden sandy path.	Therm. buried $\frac{1}{4}$ inch deep in contact with a seedling fir of this year's growth quite healthy.	Temperature of therm. under the soil of the garden.	Temperature of therm. in shade.	Temperature of wet bulb therm.
h m	°	°	°	°	°
0 21	117·5	148·2	....	88·5	64·6
1 30	118·0	149·8	....	90·5	63·5
1 50	121·0	150·8	....	90·5	65·5
2 44	114·8	148·0	....	90·0	63·5
4 12	107·5	....	....	84·5	63·5
5 Dec.					
1 15	....	....	159	98·0	68·5
1 57	....	....	159	95·5	68·5
2 57	....	....	150	91·5	68·5
4 13	....	....	119	91·2	70·5

"When however the heat communicated from the sun is confined and prevented from escape, and so forced to accumulate, very high temperatures are attained. Thus, on

23 Nov.	In a small mahogany box blackened inside, covered with window-glass fitted to the side, but without putty, and simply exposed perpendicularly to the sun's rays, an enclosed thermometer marked	° 149
24 Nov.	The same thermometer under the same circumstances, 146, 150,	152
3 Dec.	Sand heaped round the box, to cut off the contact of cold air	177
	Same box and enclosed thermometer established under an external frame of wood well sanded up at the sides, and protected by a sheet of window glass (in addition to that of the box within)—	
	$1^h\ 30^m$	207
	1 50	217·5
	2 44, with a steady breeze over the spot of exposure	218

5 Dec. Under similar form of exposure at—

0^h 19^m	224°
0 29	230
1 15	239
1 57	248
2 57	240·5

"As those temperatures far surpass that of boiling water, some amusing experiments were made by exposing eggs, fruit, meat, &c. in the same manner (Dec. 21, 1837, *et seq.*), all of which, after a moderate length of exposure, were found perfectly cooked,—the eggs being rendered hard and powdery to the centre; and on one occasion a very respectable stew of meat and vegetables was prepared, and eaten with no small relish by the entertained bystanders. I doubt not that, by multiplying the enclosing vessels, constructing them of copper blackened inside, insulating them from contact with each other by charcoal supports, surrounding the exterior one with cotton, and burying it so surrounded in dry sand, a temperature approaching to ignition might readily be commanded without the use of lenses."

Thus the heat which is absorbed by the moon's surface may therefore produce very different effects according to the nature of that surface, and to that of the substratum on which it rests. If the surface radiate heat rapidly, then that portion exposed to the sun will not be so hot as it otherwise might be, and the unilluminated face will be colder. If it radiates badly, of course the whole of the moon's surface will be hotter. This radiation will in this case consist not only of that heat which the sun has supplied, but also of heat from the interior of the moon arising from any other source.

The conducting power of the matter immediately below the moon's surface is another important element in the question respecting the nature of its climate. If it possess this power in a very low degree, the surface will, when exposed to the sun, become intensely hot; and if at the same time that surface is a bad radiator, there is scarcely any limit to the heat which may be accumulated within it.

If, on the other hand, the whole body of the moon were an exceedingly good conductor, the heat acquired from the sun might be transmitted rapidly to the opposite hemisphere, and thus equalize the temperature of the whole.

Under the varied circumstances of climate, which might arise from differences in the reflecting, the radiating, the absorbing and the conducting power of the moon's surface, as well as from different degrees of central heat, the presence of water upon its surface might produce very different effects.

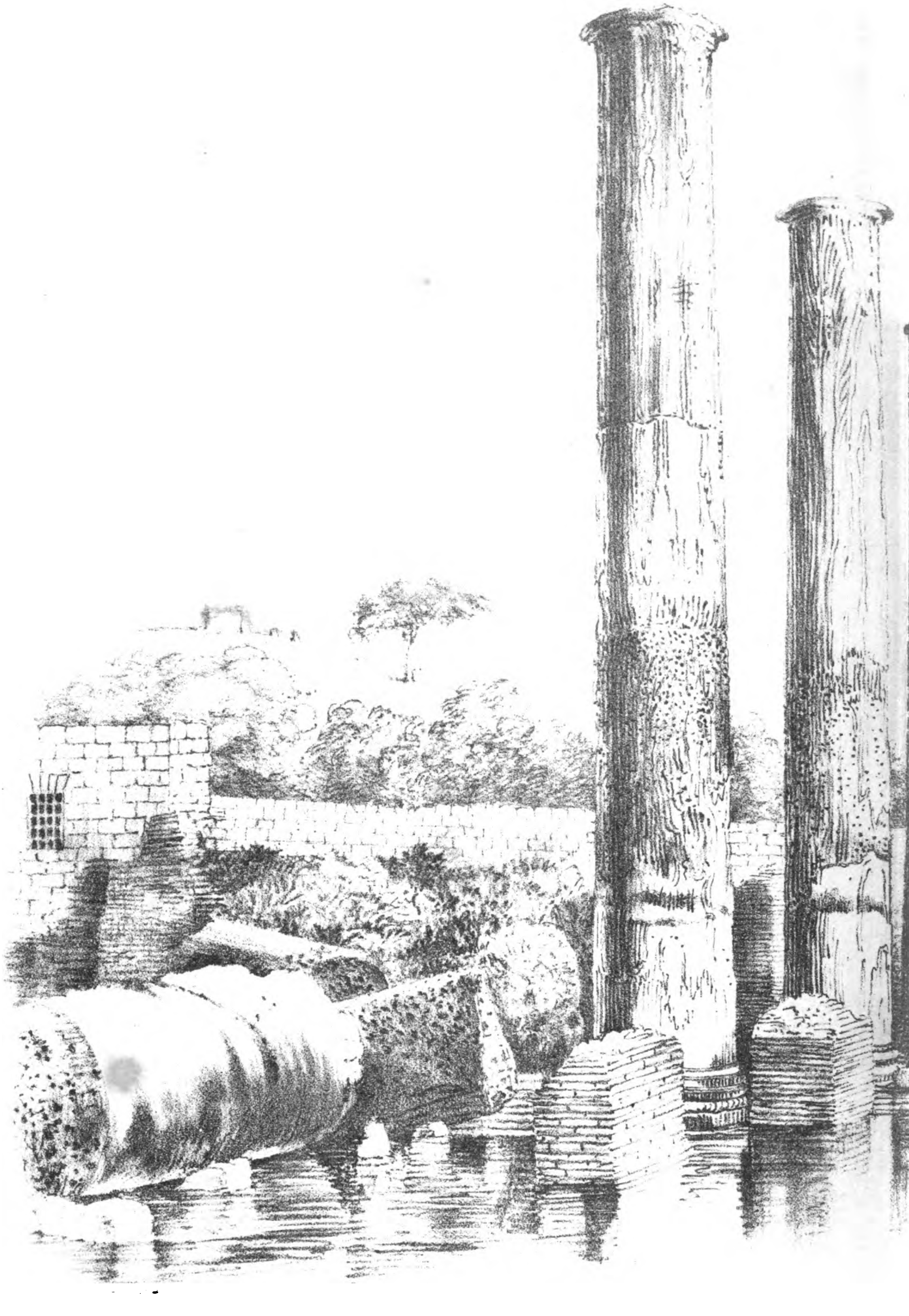
If there existed on the side of the moon opposite to the earth any sea or large expanse of water, the whole sea if very shallow might be converted into steam, which would rush towards the unilluminated edge, and there be condensed into snow. This would itself be remelted on that edge which is advancing into the sun's rays, but remain frozen on the unenlightened part. If this sea were so deep that a small portion of it remained after the evaporation produced by solar heat, then on entering the part obscured from the sun the shallow remainder might be frozen, and either remelted again by the moon's internal heat, or it might remain frozen, or partially frozen, until that portion of the lunar surface again advanced into the sun's rays.

If the moon have any atmosphere, the top of the mountains will be colder than the rest of the moon's surface; and upon these the first condensation will take place. If those craters are indeed the remains of coral lagoon islands, a new source of the bright streaks which diverge from the lunar mountains will be supplied, for the condensed water or the melting snow washing out the chalky matter contained in the ancient lagoons will be carried in channels which it will have excavated for itself, and which it will whiten by that chalky deposit.

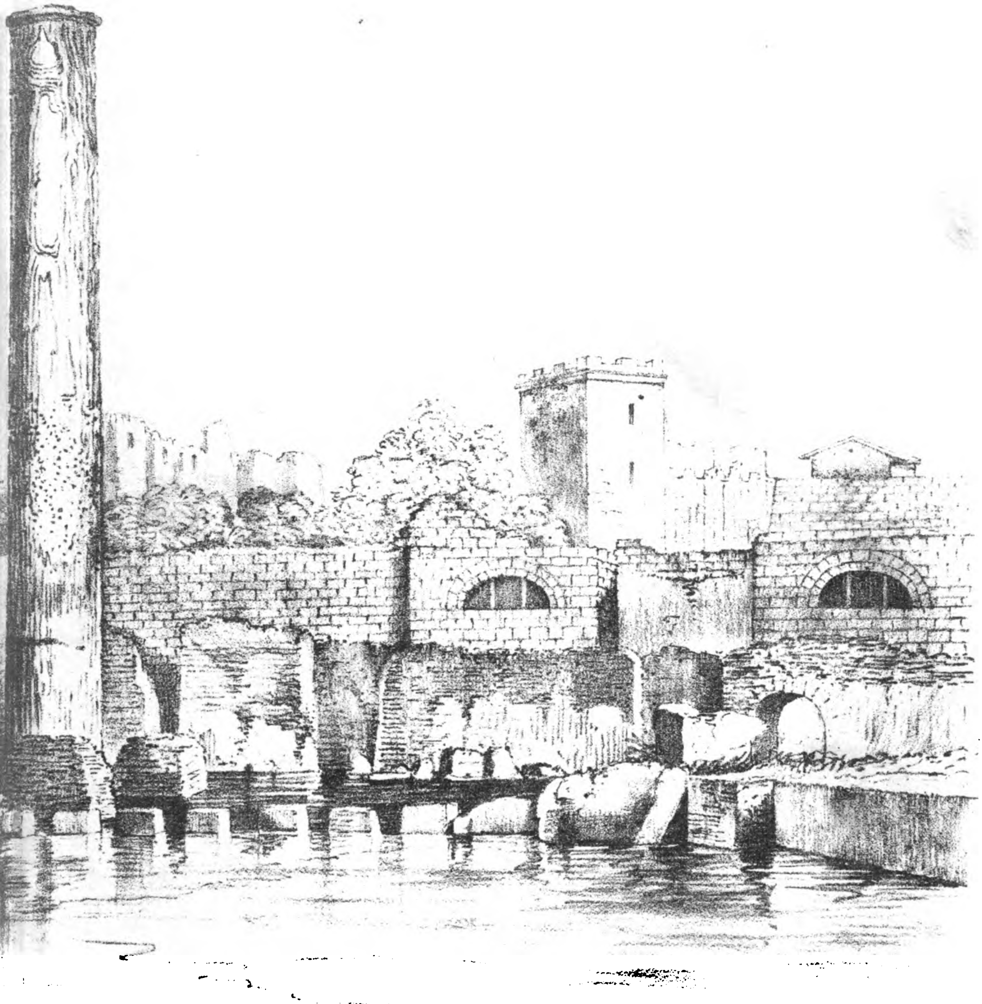
The preceding remarks are proposed entirely as speculations, whose chief use is to show that we are not entirely without principles from which we may reason on the physical structure of the moon, and that the *volcanic* theory is not the only one by which the phænomena could be explained. They may also, by throwing out for discussion an hypothesis which can as yet pretend to but slight evidence, induce those who have the means of observing the moon to discover new facts, which, whether they confirm or refute the theory, cannot fail to add to our knowledge of that body.

FINIS.

PRINTED BY RICHARD AND JOHN E. TAYLOR,
RED LION COURT, FLEET STREET.

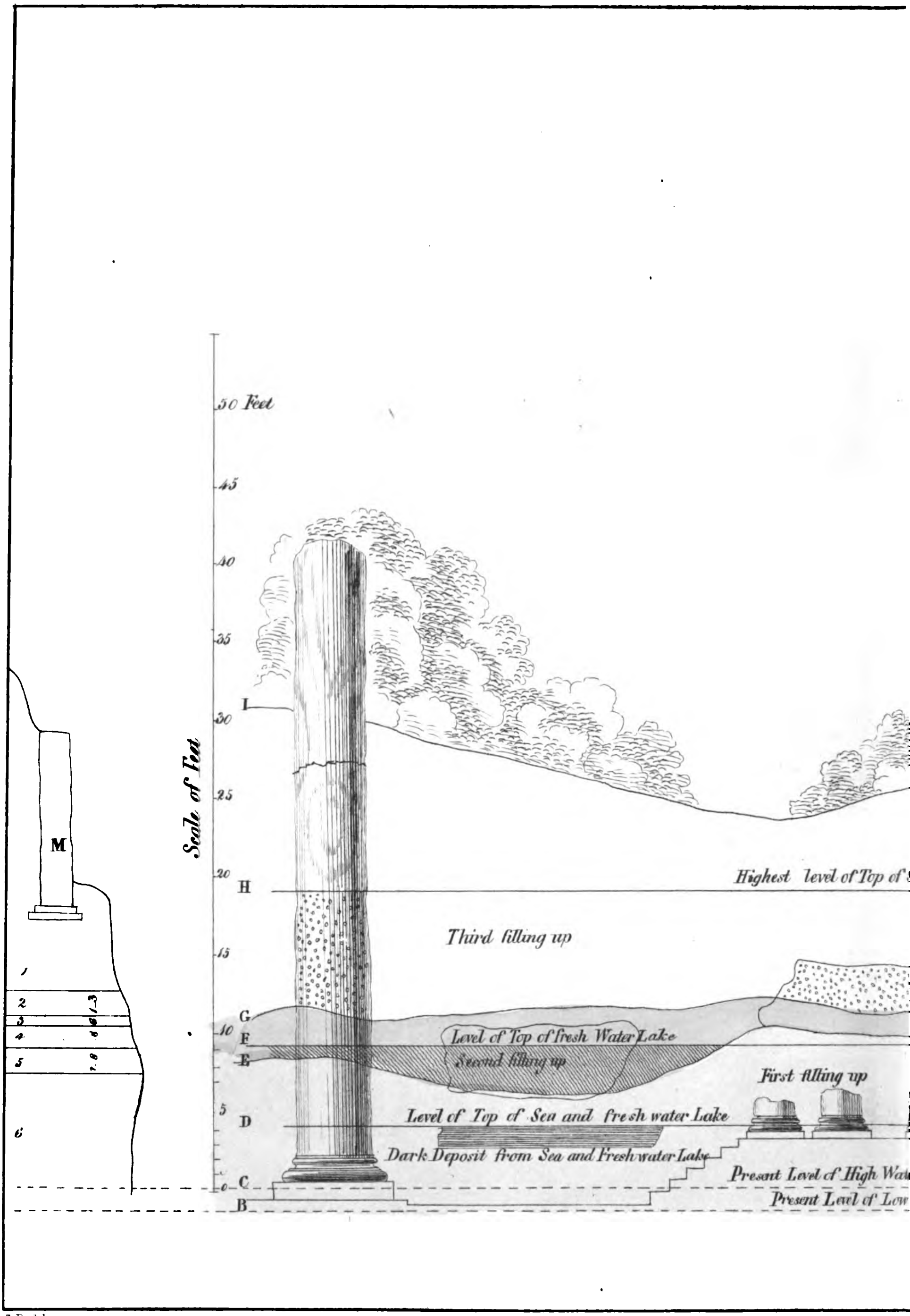


Edward J. Anson, Junr. 1836.



Reeve Brothers, Lithographers.

SERAPIS.



50 Feet
45
40
35
30
25
20
15
10
5
0
Scale of Feet
I
H
G
F
E
D
C
B
M
1
2
3
4
5
6
Highest level of Top of
Third filling up
Level of Top of fresh Water Lake
Second filling up
First filling up
Level of Top of Sea and fresh water Lake
Dark Deposit from Sea and Fresh water Lake
Present Level of High Wa
Present Level of Low

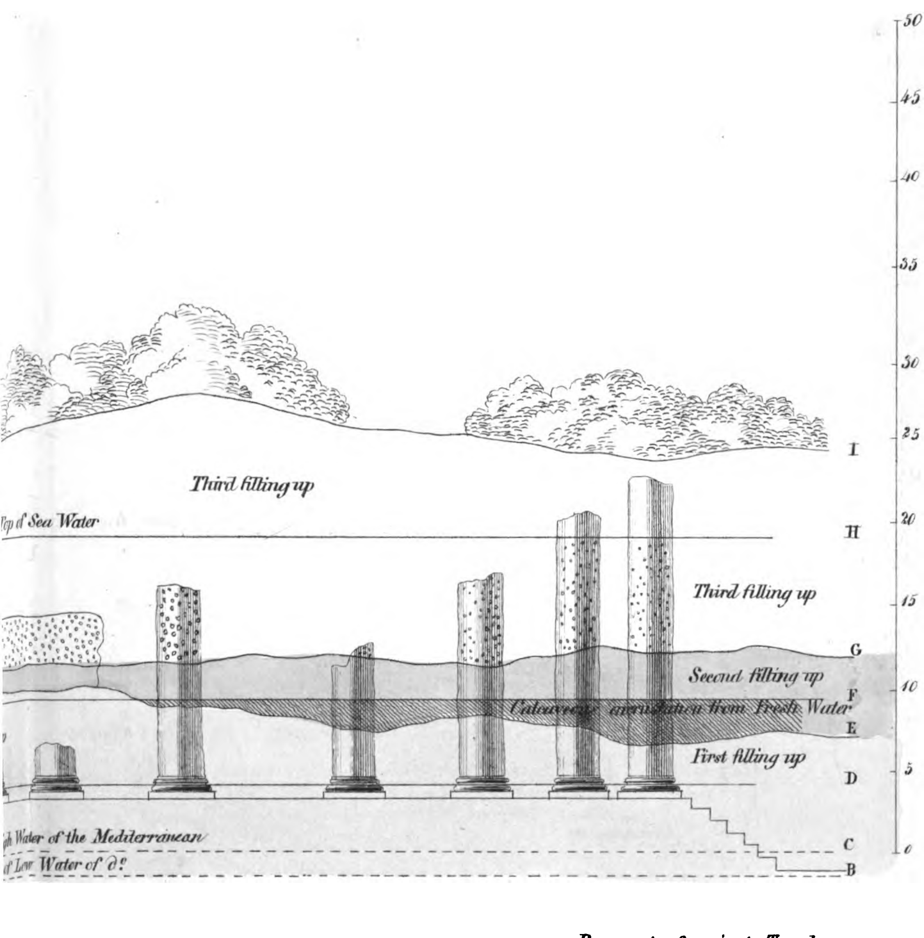
C. Babbage.

Section of the

TEMPLE OF JUPITER SERAPIS,

Shewing the Successive Changes it has undergone.

1828



Reeve, Brothers, Lithographers.

BY THE SAME AUTHOR.

Several applications having been made to the Author and to his Publishers, for detached Papers which he has from time to time written, he takes this opportunity of giving a list of those Papers, with references to the Works in which they may be found.

---

1. The Preface; jointly with Sir John Herschel.
2. On Continued Products.

} *Memoirs of the Analytical Society.* 4*to.* *Cambridge,* 1813.

3 An Essay towards the Calculus of Functions.—*Phil. Trans.* 1815.

4. An Essay towards the Calculus of Functions, Part 2.—*Phil. Trans.* 1816. p. 179.

5. Demonstrations of some of Dr. Matthew Stewart's General Theorems, to which is added an Account of some New Properties of the Circle.—*Roy. Inst. Jour.* 1816. Vol. i. p. 6.

6. Observations on the Analogy which subsists between the Calculus of Functions and other branches of Analysis.—*Phil. Trans.* 1817. p. 179.

7. Solution of some Problems by means of the Calculus of Functions.—*Roy. Inst. Jour.* 1817. p. 371.

8. Note respecting Elimination.—*Roy. Inst. Jour.* 1817. p. 355.

9. An Account of Euler's Method of solving a Problem relating to the Knight's Move at Chess.—*Roy. Inst. Jour.* 1817. p. 72.

10. On some new Methods of investigating the Sums of several Classes of Infinite Series.—*Phil. Trans.* 1819. p. 249.

11. Demonstration of a Theorem relating to Prime Numbers.—*Edin. Phil. Jour.* 1819. p. 46.

12. An Examination of some Questions connected with Games of Chance.—*Trans. of Roy. Soc. of Edin.* 1820. Vol. ix. p. 153.

13. Observations on the Notation employed in the Calculus of Functions.—*Trans. of Cam. Phil. Soc.* 1820. Vol. i. p. 63.

14. On the Application of Analysis, &c., to the Discovery of Local Theorems and Porisms.—*Trans. of Roy. Soc. of Edin.* Vol. ix. p. 337.

15. A Letter to Sir H. Davy, P.R.S. on the application of Machinery to the purpose of calculating and printing Mathematical Tables.—4to. *July,* 1822.

16. Note respecting the application of Machinery to the Calculation of Mathematical Tables.—*Memoirs of the Astron. Soc. June* 1822. Vol. i. p. 309.

17. On the Theoretical Principles of the Machinery for calculating Tables.—*Brewster's Edin. Journ. of Science.* 1823. Vol. viii. p. 122.

18. Observations on the application of Machinery to the Computations of Mathematical Tables, Dec. 1822.—*Memoirs of Astron. Soc.* 1824. Vol. i. p. 311.

BY THE SAME AUTHOR.

19. On the Determination of the General Term of a new Class of Infinite Series.—*Trans. Cam. Phil. Soc.* 1824. Vol. ii. p. 218.

20. Observations on the Measurement of Heights by the Barometer.—*Brewster's Edin. Jour. of Science,* 1824. p. 85.

21. Account of the repetition of M. Arago's Experiments on the Magnetism manifested by various substances during Rotation. By C. Babbage, Esq. and Sir John Herschel, Bart.—*Phil. Trans.* 1825. p. 467.

22. On the Diving Bell.—*Ency. Metrop.* 4to. 1826.

23. On Electric and Magnetic Rotation.—*Phil. Trans.* 1826. Vol. ii. p. 494.

24. On a method of expressing by Signs the Action of Machinery.—*Phil. Trans.* 1826. Vol. ii. p. 250.

25. On the Influence of Signs in Mathematical Reasoning.—*Trans. Cam. Phil. Soc.* 1826. Vol. ii. p. 218.

26. On Notation.—*Edin. Ency.* 4to.

27. On Porisms.—*Edin. Ency.* 4to.

28. Translation of the Differential and Integral Calculus of La Croix, 1 vol.

29. Examples to the Differential and Integral Calculus. 2 vols. 8vo.

These two works were executed in conjunction with the Rev. G. Peacock (now Dean of Ely), and Sir John Herschel, Bart.

30. A Comparative View of the different Institutions for the Assurance of Life.—1 vol. 8vo. 1826.

A German translation of this work was published for the purpose of establishing at Gotha a Society for the Assurance of Lives. At the commencement of 1847, the number of persons whose lives had been assured, was 14,564, and the amount then assured was 23,218,700 Thlr.

31. A Table of the Logarithms of the Natural Numbers, from 1 to 108,000. Stereotyped. 1 vol. 8vo. 1826.

These Logarithms were used by the computers in the whole of the Trigonometric survey of Ireland, and in that part of the English survey subsequent to their publication. There have been several impressions on different coloured paper—white, yellow, and fawn. Editions also have been published on white, yellow, and green paper, with the Preface and Introduction translated into the German and Hungarian Languages. 1834.

32. Notice respecting some Errors common to many Tables of Logarithms.—*Mem. Astron. Soc.* 4to. 1827. Vol. iii. p. 65.

33. Essay on the General Principles which regulate the Application of Machinery.—*Ency. Metrop.* 4to.

34. Reflections on the Decline of Science in England, and on some of its Causes. 4to. and 8vo. 1830.

35. Examples of the Solution of Functional Equations. 8vo.

36. Sketch of the Philosophical Characters of Dr. Wollaston and Sir H. Davy. Extracted from the *Decline of Science.*

37. Letter to T. P. Courtenay on the Proportion of Births of the two Sexes amongst Legitimate and Illegitimate Children.—*Brewster's Edin. Jour. of Science.* Vol. ii. p. 85. 1829.

BY THE SAME AUTHOR.

38. Economy of Manufactures and Machinery. 8vo. 1832.

There are American reprints, and several Translations of this Work into German, French, Italian, Spanish, and Russian.

39. Letter to Sir David Brewster, on the Advantage of a Collection of the Constants of Nature and Art.—*Brewster's Edin. Journ. of Science.* 1832. Vol. vi. p. 334. Reprinted by order of the British Association for the Promotion of Science. Cambridge, 1833. See also pp. 484, 490, Report of the Third Meeting of the British Association.

40. Letter written in Cypher, from Mr. Abraham Sharp to Mr. J. Crosthwait, 2 Feb. 1721—22, relative to a supposed error in the division of the mural arc at Greenwich. Decyphered by Mr. Babbage. See Life of Flamstead, by Mr. F. Baily. Appendix, pp. 348, 390. 4to 1835.

41. Specimen of Logarithmic Tables, printed with different coloured inks, and on variously-coloured papers, in twenty-one volumes 8vo. London. 1831.

The object of this Work, of which *one single copy only* was printed, is to ascertain by experiment the tints of the paper and colours of the inks least fatiguing to the eye.

One hundred and fifty-one variously-coloured papers were chosen, and the same two pages of my stereotype Table of Logarithms were printed upon them in inks of the following colours :—light blue, dark blue, light green, dark green, olive, yellow, light red, dark red, purple, and black.

Each of these twenty volumes contains papers of the same colour, numbered in the same order, and there are two volumes printed with each kind of ink.

The twenty-first volume contains metallic printing of the same specimen in gold, silver, and copper, upon vellum and on variously-coloured papers.

For the same purpose, about thirty-five copies of the complete table of logarithms were printed on thick drawing-paper of various tints.

An account of this work may be found in the *Edin. Journ of Science, (Brewster's,)* 1832. Vol. vi. p. 144.

42. Barometrical Observations, made at the Fall of the Staubbach, by Sir John Herschel, Bart. and C. Babbage, Esq.—*Brewster's Edin. Journ. of Science.* 1832. Vol. vi. p. 224.

43. The Ninth Bridgewater Treatise 8vo. May, 1837; Second Edition. Jan. 1838.

44. An Essay on the Principles of Tools for turning and planing metals (inserted in the Second Volume of Turning and Mechanical Manipulation of the late Charles Holtzapfel), 1846.

45. Observations on the Temple of Serapis at Pozzuoli, near Naples, with an attempt to explain the causes of the frequent elevation and depression of large portions of the earth's surface in remote periods, and to prove that those causes continue in action at the present time.—*Proceedings of the Geological Society.* 1847.

46. The same Memoir, with a Supplement, Conjectures on the Physical Condition of the Surface of the Moon. 8vo. Privately printed. 1847.

R. CLAY, PRINTER, BREAD STREET HILL.