

**PRINCIPLES OF GEOLOGY.**



“ Amid all the revolutions of the globe the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents have been changed in all their parts ; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same.”—PLAXFAIR, *Illustrations of the Huttonian Theory*, § 374.



T. Bradley, Sc.

*Present state of the Temple of Serapis at Pozzuoli.*

*London, Published by John Murray, Albemarle St June 1830.*

P R I N C I P L E S

OF

G E O L O G Y,

BEING

AN ATTEMPT TO EXPLAIN THE FORMER CHANGES  
OF THE EARTH'S SURFACE,

BY REFERENCE TO CAUSES NOW IN OPERATION.

---

BY

CHARLES LYELL, Esq., F.R.S.

*FOR. SEC. TO THE GEOL. SOC., &c.*

---

IN TWO VOLUMES.

VOL. I.

---

LONDON:

JOHN MURRAY, ALBEMARLE-STREET,

---

MDCCLXXX.

LONDON :  
Printed by WILLIAM CLOWNS,  
Stamford Street.

# CONTENTS.

PAGE

## CHAPTER I.

Geology defined—Compared to History—Its relation to other Physical Sciences—Its distinctness from all—Not to be confounded with Cosmogony . . . . . 1

## CHAPTER II.

Oriental Cosmogony—Doctrine of the successive destruction and renovation of the world—Origin of this doctrine—Common to the Egyptians—Adopted by the Greeks—System of Pythagoras—Of Aristotle—Dogmas concerning the extinction and reproduction of genera and species—Strabo's theory of elevation by earthquakes—Pliny—Concluding remarks on the knowledge of the Ancients . . . . . 5

## CHAPTER III.

Arabian writers of the Tenth century—Persecution of Omar—Cosmogony of the Koran—Early Italian writers—Fracastoro—Controversy as to the real nature of organized fossils—Fossil shells attributed to the Mosaic deluge—Palissy—Steno—Scilla—Quirini—Boyle—Plot—Hooke's Theory of Elevation by earthquakes—His speculations on lost species of animals—Ray—Physico-theological writers—Woodward's Diluvial Theory—Burnet—Whiston—Hutchinson—Leibnitz—Vallisneri—Lazzoro Moro—Generelli—Buffon—His theory condemned by the Sorbonne as unorthodox—Buffon's declaration—Targioni—Arduino—Michell—Catcott—Raspe—Fortis—Testa—Whitehurst—Pallas—Saussure , , , , , 21

## CHAPTER IV.

Werner's application of Geology to the art of Mining—Excursive character of his lectures—Enthusiasm of his pupils—His authority—His theoretical errors—Desmarest's map and description of Auvergne—Controversy between the Vulcanists and Neptunists—Intemperance of the rival Sects—Hutton's theory of the Earth—His discovery of granite veins—Originality of his views—Why opposed—Playfair's illustrations—Influence of Voltaire's writings on Geology—Imputations cast on the Huttonians by Williams, Kirwau, and De Luc—Smith's map of England—Geological Society of London—Progress of the Science in France—Growing importance of the study of organic remains . . . . . 55

## CHAPTER V.

Review of the causes which have retarded the progress of Geology—Effects of prepossessions in regard to the duration of past time—Of prejudices arising from our peculiar position as inhabitants of the land—Of those occasioned by our not seeing subterranean changes now in progress—All these causes combine to make the former course of Nature appear different from the present—Several objections to the assumption, that existing causes have produced the former changes of the earth's surface, removed by modern discoveries . . . . . 76

## CHAPTER VI.

Proofs that the climate of the Northern hemisphere was formerly hotter—Direct proofs from the Organic remains of the Sicilian and Italian strata—Proofs from analogy derived from extinct Quadrupeds—Imbedding of Animals in Icebergs—Siberian Mammoths—Evidence in regard to temperature, from the fossil remains of tertiary and secondary rocks—From the plants of the coal formation . . . . . 92

## CHAPTER VII.

On the causes of vicissitudes in climate—Remarks on the present diffusion of heat over the globe—On the dependence of the mean temperature on the relative position of land and sea—Isothermal lines—Currents from equatorial regions—Drifting of Icebergs—Different temperature of Northern and Southern hemispheres—Combination of causes which might produce the extreme cold of which the earth's surface is susceptible—On the conditions necessary for the production of the extreme of heat, and its probable effects on organic life 104



## CHAPTER VIII.

Geological proofs that the geographical features of the northern hemisphere, at the period of the deposition of the carboniferous strata, were such as would, according to the theory before explained, give rise to an extremely hot climate—Origin of the transition and mountain limestones, coal-sandstones, and coal—Change in the physical geography of northern latitudes, between the era of the formation of the carboniferous series and the lias—Character of organic remains, from the lias to the chalk inclusive—State of the surface when these deposits originated—Great accession of land, and elevation of mountain-chains, between the consolidation of the newer secondary and older tertiary rocks—Consequent refrigeration of climate—Abrupt transition from the organic remains of the secondary to those of the tertiary strata—Maestricht beds—Remarks on the theory of the diminution of central heat . . . . . 125

## CHAPTER IX.

Theory of the progressive development of organic life considered—Evidence in its support wholly inconclusive—Vertebrated animals in the oldest strata—Differences between the organic remains of successive formations—Remarks on the comparatively modern origin of the human race—The popular doctrine of successive development not confirmed by the admission that man is of modern origin—In what manner the change in the system caused by the introduction of man affects the assumption of the uniformity of the past and future course of physical events . . . . . 144

## CHAPTER X.

Division of the subject into changes of the organic and inorganic world—Inorganic causes of change divided into the aqueous and igneous—Aqueous causes—Destroying and transporting power of running water—Sinuosities of rivers—Two streams when united do not occupy a bed of double surface—Heavy matter removed by torrents and floods—Recent inundations in Scotland—Effects of ice in removing stones—Erosion of chasms through hard rocks—Excavations in the lavas of Etna by Sicilian rivers—Gorge of the Simeto—Gradual recession of the cataracts of Niagara—Speculations as to the time required for their reaching Lake Erie . . . . . 167

## CHAPTER XI.

Action of running water, *continued*—Course of the Po—Desertion of its old channel—Artificial embankments of the Po, Adige, and other Italian rivers—Basin of the Mississippi—Its meanders—Islands—Shifting of its

	PAGE
course—Raft of the Atchafalaya—Drift wood—New-formed lakes in Louisiana—Earthquakes in the valley of the Mississippi—Floods caused by landslips in the White mountains—Bursting of a lake in Switzerland—Devastations caused by the Anio at Tivoli . . . . .	183

## CHAPTER XII.

Difference between the transporting power of springs and rivers—Many springs carry matter from below upwards—Mineral ingredients most abundant in springs—Connexion of mineral waters with volcanic phenomena—Calcareous springs—Travertin of the Elsa—Baths of San Vignone, and of San Filippo, near Radicofani—Spheroidal structure in travertin, as in English magnesian limestone—Bulicami of Viterbo—Lake of the Solfatara, near Rome—Travertin at Cascade of Tivoli—Ferruginous springs—Cementing and colouring property of iron—Brine springs—Carbonated springs—Disintegration of Auvergne granite—Caverns in limestone—Petroleum springs—Pitch lake of Trinidad . . . . .	198
--	-----

## CHAPTER XIII.

Reproductive effects of running water—Division of deltas into lacustrine, mediterranean, and oceanic—Lake deltas—Growth of the delta of the Rhone in the Lake of Geneva—Chronological computations of the age of deltas—Recent deposits in Lake Superior—Deltas of inland seas—Rapid shallowing of the Baltic—Arguments for and against the hypothesis of Celsius—Elevated beaches on the coast of Sweden—Marine delta of the Rhone—Various proofs of its increase—Stony nature of its deposits—Delta of the Po, Adige, Isonzo, and other rivers entering the Adriatic—Rapid conversion of that gulf into land—Mineral characters of the new deposits—Delta of the Nile—Its increase since the time of Homer—Its growth why checked at present . . . . .	220
--	-----

## CHAPTER XIV.

Oceanic deltas—Delta of the Ganges and Burrampooter—Its size, rate of advance, and nature of its deposits—Formation and destruction of islands—Abundance of crocodiles—Inundations—Delta of the Mississippi—Deposits of drift wood—Gradual filling up of the Yellow Sea—Rennell's estimate of the mud carried down by the Ganges—Formation of valleys illustrated by the growth of deltas—Grouping of new strata in general—Convergence of deltas—Conglomerates—Various causes of stratification—Direction of laminæ—Remarks on the interchange of land and sea . . . . .	240
---	-----

## CHAPTER XV.

Destroying and transporting effects of Tides and Currents—Shifting of their position—Differences in the rise of the tides—Causes of currents—Action of the sea on the British coast—Shetland Islands—Large blocks removed—Effects of lightning—Breach caused in a mass of porphyry—Isles reduced to clusters of rocks—Orkney Isles—East coast of Scotland—Stones thrown up on the Bell Rock—East coast of England—Waste of the cliffs of Holderness, Norfolk, and Suffolk—Silting up of Estuaries—Origin of submarine forests—Yarmouth estuary—Submarine forests—Suffolk coast—Dunwich—Essex coast—Estuary of the Thames—Goodwin Sands—Coast of Kent—Formation of Straits of Dover—Coast of Hants—Coast of Dorset—Portland—Origin of the Chesel Bank—Cornwall—Lionnesse tradition—Coast of Brittany . . . . . 256

## CHAPTER XVI.

Action of Tides and Currents, *continued*—Inroads of the sea upon the delta of the Rhine in Holland—Changes in the arms of the Rhine—Estuary of the Bies Bosch, formed in 1421—Formation of the Zuyder Zee, in the 13th century—Islands destroyed—Delta of the Ems converted into a bay—Estuary of the Dollart formed—Encroachment of the sea on the coast of Sleswick—Inroads on the eastern shores of North America—Tidal wave called the Bore—Influence of tides and currents on the mean level of seas—Action of currents on inland lakes and seas—Baltic—Cimbrian deluge—Straits of Gibraltar—Under currents—Shores of Mediterranean—Rocks transported on floating icebergs—Dunes of blown sand—Sands of the Libyan Desert—De Luc's natural chronometers . . . . . 285

## CHAPTER XVII.

Reproductive effects of Tides and Currents—Silting up of Estuaries does not compensate the loss of land on the borders of the ocean—Bed of the German Ocean—Composition and extent of its sand-banks—Strata formed by currents on the southern and eastern shores of the Mediterranean—Transportation by currents of the sediment of the Amazon, Orinoco, and Mississippi—Stratification—Concluding remarks . . . . . 303

## CHAPTER XVIII.

Division of igneous agents into the volcano and the earthquake—Distinct regions of subterranean disturbance—Region of the Andes—System of volcanos extending from the Aleutian Isles to the Moluccas—Polynesian archi-

	PAGE
pelago—Volcanic region extending from the Caspian Sea to the Azores— Former connexion of the Caspian with Lake Aral and the Sea of Azof—Low steppes skirting these seas—Tradition of deluges on the shores of the Bos- phorus, Hellespont, and the Grecian archipelago—Periodical alternation of earthquakes in Syria and Southern Italy—Western limits of the European region—Earthquakes rarer and more feeble in proportion as we recede from the centres of volcanic action—Extinct volcanos not to be included in lines of active vents . . . . .	312

### CHAPTER XIX.

History of the volcanic eruptions in the district round Naples—Early con- vulsions in the island of Ischia—Numerous cones thrown up there—Epomeo not an habitual volcano—Lake Avernus—The Solfatara—Renewal of the eruptions of Vesuvius A.D. 79—Pliny's description of the phenomena—Re- marks on his silence respecting the destruction of Herculaneum and Pompeii —Subsequent history of Vesuvius—Lava discharged in Ischia in 1302— Pause in the eruptions of Vesuvius—Monte Nuovo thrown up—Uniformity of the volcanic operations of Vesuvius and the Phlegræan Fields in ancient and modern times . . . . .	326
---	-----

### CHAPTER XX.

Dimensions and structure of the cone of Vesuvius—Dikes in the recent cone, how formed—Section through Vesuvius and Somma—Vesuvian lavas and minerals—Effects of decomposition of lava—Alluvions called "aqueous lavas"—Origin and composition of the matter enveloping Herculaneum and Pompeii—Controversies on the subject—Condition and contents of the buried cities—Proofs of their having suffered by an earthquake—Small number of skeletons—State of preservation of animal and vegetable substances—Rolls of Papyrus—Probability of future discoveries of MSS.—Stabiæ—Torre del Greco—Concluding remarks on the destroying and renovating agency of the Campanian volcanos . . . . .	340
---	-----

### CHAPTER XXI.

External physiognomy of Etna—Minor cones produced by lateral eruptions  
—Successive obliteration of these cones—Early eruptions of Etna—Monti  
Rossi thrown up in 1669—Great fissure of S. Lio—Towns overflowed by  
lava—Part of Catania destroyed—Mode of the advance of a current of lava

—Excavation of a church under lava—Series of subterranean caverns—  
 Linear direction of cones formed in 1811 and 1819—Flood produced in 1755  
 by the melting of snow during an eruption—A glacier covered by a lava-  
 stream on Etna—Volcanic eruptions in Iceland—New island thrown up in  
 1783—Two lava-currents of Skaptár Jokul in the same year—Their immense  
 volume—Eruption of Jorullo in Mexico—Humboldt's Theory respecting the  
 convexity of the Plain of Malpais . . . . . 361

CHAPTER XXII.

Volcanic Archipelagos—The Canaries—Eruptions of the Peak of Teneriffe  
 —Cones thrown up in Lancerote in 1730-36—Pretended distinction between  
 ancient and modern lavas—Recent formation of oolitic travertine in Lan-  
 cerote—Grecian Archipelago—Santorin and its contiguous isles—Von  
 Buch's Theory of "Elevation Craters" considered—New islands thrown up  
 in the Gulf of Santorin—Supposed "Crater of Elevation" in the Isle of  
 Palma—Description of the Caldera of Palma—Barren island in the Bay of  
 Bengal—Origin of the deep gorge on the side of "Elevation Craters"—  
 Stratification of submarine volcanic products—Causes of the great size of  
 the craters of submarine volcanos—Cone of Somma, formed in the same  
 manner as that of Vesuvius—Mineral composition of volcanic products—  
 Speculations respecting the nature of igneous rocks produced at great depths,  
 by modern volcanic eruptions . . . . . 380

CHAPTER XXIII.

Earthquakes and their effects—Deficiency of ancient accounts—Ordinary  
 atmospheric phenomena—Changes produced by earthquakes in modern times  
 considered in chronological order—Earthquake in Murcia, 1829—Bogota in  
 1827—Chili in 1822—Great extent of country elevated—Aleppo in 1822—  
 Ionian Isles in 1820—Island of Sumbawa in 1815—Town of Tomboro sub-  
 merged—Earthquake of Cutch in 1819—Subsidence of the delta of the  
 Indus—Earthquake of Caraccas in 1812—South Carolina in 1811—Geo-  
 graphical changes in the valley of the Mississippi—Volcanic convulsions in  
 the Aleutian Islands in 1806—Reflections on the earthquakes of the eight-  
 teenth century—Earthquake in Quito, 1797—Cumana, 1797—Caraccas,  
 1790—Sicily, 1790—Java, 1786—Sinking down of large tracts . . . . . 398

CHAPTER XXIV.

Earthquake in Calabria, February 5th, 1783—Shocks continued to the end  
 of the year 1786—Authorities—Extent of the area convulsed—Geological

structure of the district—Difficulty of ascertaining changes of relative level even on the sea-coast—Subsidence of the quay at Messina—Shift or fault in the Round Tower of Terranuova—Movement in the stones of two obelisks—Alternate opening and closing of fissures—Cause of this phenomenon—Large edifices engulfed—Dimensions of new caverns and fissures—Gradual closing in of rents—Bounding of detached masses into the air—Landslips—Buildings transported entire, to great distances—Formation of fifty new lakes—Currents of mud—Small funnel-shaped hollows in alluvial plains—Fall of cliffs along the sea-coast—Shore near Scilla inundated—State of Stromboli and Etna during the shocks—Illustration afforded by this earthquake of the mode in which valleys are formed	412
---	-----

## CHAPTER XXV.

Earthquakes of the eighteenth century, <i>continued</i> —Java, 1772—Truncation of a lofty cone—Caucasus, 1772—Java, 1771—Colombia, 1766—Chili, 1760—Azores, 1757—Lisbon, 1755—Sinking down of the quay to the depth of six hundred feet—Shocks felt throughout Europe, Northern Africa, and the West Indies—Great wave—Shocks felt at sea—St. Domingo, 1751—Conception Bay, 1750—Permanent elevation of the bed of the sea to the height of twenty-four feet—Peru, 1746—Kamtschatka, 1737—Martinique, 1727—Iceland, 1725—Teneriffé, 1706—Java, 1699—Landslips obstruct the Batavian and Tangaran rivers—Quito, 1698—Sicily, 1693—Subsidence of land—Moluccas, 1693—Jamaica, 1692—Large tracts engulfed—Portion of Port Royal sunk from twenty to fifty feet under water—The Blue Mountains shattered—Reflections on the amount of change in the last one hundred and forty years—Proofs of elevation and subsidence of land on the coast of the Bay of Baiæ—Evidence of the same afforded by the present state of the Temple of Serapis	436
---	-----

## CHAPTER XXVI.

Magnitude of the subterranean changes produced by earthquakes at great depths below the surface—Obscurity of geological phenomena no proof of want of uniformity in the system, because subterranean processes are but little understood—Reasons for presuming the earthquake and volcano to have a common origin—Probable analogy between the agency of steam in the Icelandic geysers, and in volcanos during eruptions—Effects of hydrostatic pressure of high columns of lava—Of the condensation of vapours in the interior of the earth—That some earthquakes may be abortive eruptions—Why all volcanos are in islands or maritime tracts—Gases evolved from

volcanos—Regular discharge of heat and of gaseous and earthy matter from the subterranean regions—Cause of the wave-like motion and of the retreat of the sea during earthquakes—Difference of circumstances of heat and pressure at great depths—Inferences from the superficial changes brought about by earthquakes—In what matter the repair of land destroyed by aqueous causes takes place—Proofs that the sinking in of the earth's crust somewhat exceeds the forcing out by earthquakes—Geological consequences of this hypothesis, that there is no ground for presuming that the degree of force exerted by subterranean movements in a given time has diminished—Concluding remarks . . . . . 460

---

ERRATA.

<i>Page</i>	<i>35</i>	<i>line</i>	<i>2</i>	<i>from</i>	<i>top,</i>	<i>for</i>	<i>or</i>	<i>read</i>	<i>and</i>
—	35	—	13	—	bottom,	—	Alp	—	Alps
—	150	—	12	—	top,	—	law	—	laws
—	154	—	11	—	do.,	—	Of	—	In
—	190	—			heading	—	LOUISLAND	—	LOUISIANA
—	226	—			do.	—	DELTA	—	DELTAS
—	326	—	6	—	bottom	—	Pl. 3	—	Pl. 2.

# LIST OF PLATES AND WOOD-CUTS

IN

## THE FIRST VOLUME.

---

### PLATES.

*Frontispiece.*—This representation of the present state of the Temple of Serapis has been carefully reduced from that given by the Canonico Andrea de Jorio in his 'Ricerche sul Tempio di Serapide, in Puzzuoli.' Napoli, 1820.

Plate 1., *fig. 1.*—Shewing that a chain of volcanic vents surrounds the Asiatic Islands, in the same manner as a continuation of the same line skirts the eastern borders of the continent of Asia. This plate is copied from plate 13 of Von Buch's *Phys. Besch. der Canarischen Inseln.* Berlin, 1825. The position however of some of the volcanos, and the outline of several of the islands, has been corrected.

*Fig. 2.*—Shewing the direction of the trachytic islands from N.W. to S.E. parallel to the principal mountain-chains of Greece, as also to the Grecian islands which constitute a continuation of the mountains of the main-land, and are of the same mineral composition. This plate is also copied from Von Buch, plate 12, p. 318.

Plate 2., *fig. 1.*—View of the islands of Ischia and Procida, with part of the coast of Misenum, taken from part of plate 17 of Sir W. Hamilton's *Campi Phlegræi.*

*Fig. 2.*—Map of the Volcanic district of Naples. This map is copied from one constructed by G. P. Scrope, Esq., to illustrate a memoir in the *Geol. Trans.* vol. ii., part 3, from unpublished maps of Captain Smyth, R.N., p. 326.

---

### WOOD-CUTS.

No.	PAGE
1. Transverse section of the Italian peninsula . . . .	136
2. Diagram explanatory of the sinuosity of river-courses . . . .	170
3. Diagram shewing the recent excavation of lava at the foot of Etna by the river Simeto . . . . .	178
4. Section of travertin of San Vignone . . . . .	202



No.	PAGE
5. Section of spheroidal concretionary travertin seen in descending from the Temple of Vesta, under the Cascade of Tivoli . . .	209
6. Section on the banks of the Arve at its confluence with the Rhone, shewing the stratification of deposits where currents meet . . .	254
7. Cut, representing stony fragments drifted by the sea at Northmavine, Shetland . . . . .	260
8. View of the 'Grind of the Navir,' a passage forced by the sea through rocks of hard porphyry in the Shetland Isles . . . . .	261
9. Granitic rocks named the Drongs, between Papa Stour and Hillswick Ness, Shetland . . . . .	262
10. Drongs to the south of Hillswick Ness, Shetland . . . . .	263
11. View of Monte Nuovo, formed in the Bay of Baiæ, September 29th, 1538 . . . . .	335
12. View of the volcanos of the Phlegræan Fields . . . . .	336
13. Diagram exhibiting a supposed section of Vesuvius and Somma . . . . .	344
14. View of Monti Rossi on the flanks of Etna, formed in 1669 . . . . .	364
15. Chart and section of Santorin and the contiguous islands in the Grecian Archipelago . . . . .	385
16. View of the Isle of Palma, and of the Caldera in its centre . . . . .	388
17. View of the cone and crater of Barren Island in the Bay of Bengal . . . . .	390
18. Supposed section of the same . . . . .	393
19. Deep fissure near Polistena in Calabria caused by the earthquake of 1783 . . . . .	417
20. Shift or fault in the round tower of Terranuova in Calabria occasioned by the earthquake of 1783 . . . . .	417
21. Shift in the stones of two obelisks in the Convent of S. Bruno . . . . .	418
22. Fissures near Jerocarne in Calabria, caused by the earthquake of 1783 . . . . .	419
23. Chasm formed by the earthquake near Oppido in Calabria . . . . .	420
24. Chasm in the hill of St. Angelo, near Soriano in Calabria caused by the earthquake in 1783 . . . . .	421
25. Circular pond near Polistena in Calabria caused by the same earthquake . . . . .	422
26. Change of the surface at Fra Ramondo, near Soriano in Calabria . . . . .	425
27. Landslips near Cinquefrondi caused by earthquake of 1783 . . . . .	427
28. Circular hollows in the plain of Rosarno formed by the same earthquake . . . . .	428
29. Section of one of them . . . . .	429
30. Ground plan of the coast of the Bay of Baiæ in the environs of Puzzuoli . . . . .	450
31. Two sections, the one exhibiting the relation of the recent marine deposits to the more ancient in the Bay of Baiæ to the north of Puzzuoli, and the other exhibiting the same relation to the south-east . . . . .	450
32. View of the crater of the Great Geyser in Iceland . . . . .	464
33. Supposed section of the subterranean reservoir and pipe of a Geyser in Iceland . . . . .	464

