

P R I N C I P L E S

OF

GEOLOGY,

BEING

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

BY REFERENCE TO CAUSES NOW IN OPERATION.

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BY

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IN THREE VOLUMES.

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TO

RODERICK IMPEY MURCHISON, Esq., F.R.S.,

&c. &c. &c.

LATE PRESIDENT OF THE GEOLOGICAL SOCIETY.

MY DEAR MURCHISON,

I HAVE great pleasure in dedicating this volume to you, as it contains the results of some of our joint labours in the field, in Auvergne, Velay, and Piedmont—results which had not yet been communicated to the public through any other channel.

When we quitted England together for a tour on the continent, in May, 1828, the first sketch only of my ‘Principles of Geology’ was finished. Since that time you have watched the progress of the work with friendly interest, and, as President of the Geological Society, have twice expressed in your Anniversary Addresses, your participation in many of my views, which were warmly controverted by others. The eulogy which you have lately pronounced from the chair, on the last part of my work, (whether I attribute your approval to the exercise of an unbiassed judgment or to the partiality of a friend,) could not fail to be most gratifying to my feelings, and I trust that you will long enjoy health and energy to continue to promote with enthusiasm the advancement of your favourite science.

Believe me, my dear Murchison,

Yours, &c. &c.

CHARLES LYELL.



## P R E F A C E.

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THE original MS. of the 'Principles of Geology' was delivered to the publisher at the close of the year 1827, when it was proposed that it should appear in the course of the year following, in two volumes octavo. Since that time many causes have concurred to delay the completion of the work, and, in some degree, to modify the original plan. In May, 1828, when the preliminary chapters on the History of Geology, and some others which follow them in the first volume, were nearly finished, I became anxious to visit several parts of the continent, in order to acquire more information concerning the tertiary formations. Accordingly, I set out in May, 1828, in company with Mr. Murchison, on a tour through France and the north of Italy, where we examined together many districts which are particularly mentioned in the body of this work. We visited Auvergne, Velay, Cantal, and the Vivarais, and afterwards the environs of Aix, in Provence, and then passed by the Maritime Alps to Savona, thence crossing to Piedmont by the Valley of the Bormida.

At Turin we found Signor Bonelli engaged in the arrangement of a large collection of tertiary shells

obtained chiefly from the Italian strata; and as I had already conceived the idea of classing the different tertiary groups, by reference to the proportional number of recent species found fossil in each, I was at pains to learn what number Signor Bonelli had identified with living species, and the degree of precision with which such identifications could be made. With a view of illustrating this point, he showed us suites of shells common to the Subapennine beds and to the Mediterranean, pointing out that in some instances not only the ordinary type of the species, but even the different varieties had their counterparts both in the fossil and recent series. The same naturalist informed us that the fossil shells of the hill of the Superga, at Turin, differed as a group from those of Parma and other localities of the Subapennine beds of northern Italy; and, on the other hand, that the characteristic shells of the Superga agreed with the species found at Bordeaux and other parts of the South of France.

I was the more struck with this remark, as Mr. Murchison and myself had already inferred that the highly-inclined strata of the Valley of the Bormida, which agree with those of the Superga, were older than the more horizontal Subapennine marls, by which the plains of the Tanaro and the Po are skirted.

When we had explored some parts of the Vicentin together, Mr. Murchison re-crossed the Alps, while I directed my course to the south of Italy, first staying

at Parma, where I studied, in the cabinets of Signor Guidotti, a beautiful collection of Italian tertiary shells, consisting of more than 1000 species, many of which had been identified with living testacea. Signor Guidotti had not examined his fossils with reference to their bearing on geological questions, but computed, on a loose estimate, that there were about 30 per cent. of living species in the Subapennine beds. I then visited Florence, Sienna, and Rome, and the results of my inquiries respecting the tertiary strata of those territories will be found partly in the body of the work, and partly in the catalogues given in Appendix II.

On my arrival at Naples I became acquainted with Signor O. G. Costa, who had examined the fossil shells of Otranto and Calabria, and had collected many recent testacea from the seas surrounding the Calabrian coasts. His comparison of the fossil and living species had led him to a very different result in regard to the southern extremity of Italy, from that to which Signors Guidotti and Bonelli had arrived in regard to the north, for he was of opinion that few of the tertiary shells were of extinct species. In confirmation of this view, he showed me a suite of fossil shells from the territory of Otranto, in which nearly all the species were recent.

In October, 1828, I examined Ischia, and obtained from the strata of that island the fossil shells named in Appendix II., p. 57. They were all, with two or

three exceptions, recognized by Signor Costa as species now inhabiting the Mediterranean, a circumstance which greatly astonished me, as I procured some of them at the height of 2000 feet above the level of the sea (Vol. iii. p. 126).

Early in November, 1828, I crossed from Naples to Messina, and immediately afterwards examined Etna, and collected on the flanks of that mountain, near Trezza, the fossil shells alluded to in the third volume (p. 79, and Appendix II., p. 53). The occurrence of shells in this locality was not unknown to the naturalists of Catania, but having been recognized by them as *recent* species, they were supposed to have been carried up from the sea-shore to fertilize the soil, and therefore disregarded. Their position is well known to many of the peasants of the country, by whom the fossils are called 'roba di diluvio.'

In the course of my tour I had been frequently led to reflect on the precept of Descartes, 'that a philosopher should once in his life doubt every thing he had been taught;' but I still retained so much faith in my early geological creed as to feel the most lively surprise, on visiting Sortino, Pentalica, Syracuse, and other parts of the Val di Noto, at beholding a limestone of enormous thickness filled with recent shells, or sometimes with the mere casts of shells, resting on marl in which shells of Mediterranean species were imbedded in a high state of preservation. All idea of attaching a high antiquity to a regularly stratified



limestone, in which the casts and impressions of shells alone were discernible, vanished at once from my mind. At the same time, I was struck with the identity of the associated igneous rocks of the Val di Noto with well known varieties of 'trap' in Scotland and other parts of Europe, varieties, which I had also seen entering largely into the structure of Etna. I occasionally amused myself with speculating on the different rate of progress which Geology might have made, had it been first cultivated with success at Catania, where the phenomena above alluded to, and the great elevation of the modern tertiary beds in the Val di Noto, and the changes produced in the historical era by the Calabrian earthquakes, would have been familiarly known.

From Cape Passaro I passed on by Spaccaforno and Licata to Girgenti, where I abandoned my design of exploring the western part of Sicily, that I might return again to the Val di Noto and the neighbourhood of Etna, and verify the discoveries which I had made. With this view I travelled by Caltanissetta, Piazza, Caltagirone, Vizzini, Militello, Palagonia, Lago Naftia, and Radusa, to Castrogiovanni, and from thence to Palermo, at which last place I procured the shells named in Appendix II. p. 55. The sections on this new route confirmed me in my first opinions respecting the Val di Noto, as will appear by the 6th, 8th, and 9th chapters of the third Volume.

When I again reached Naples, in January, 1829, I

found that Signor O. G. Costa had examined the tertiary fossils which I had sent to him from different parts of Sicily, and declared them to be for the most part of recent species. I then bent my course homeward, seeing at Genoa, Professor Viviani and Dr. Sasso, the last of whom put into my hands his memoirs on the strata of Albenga (see vol. iii. p. 166), in which I found, that, according to his list of shells, the tertiary formations at the foot of the maritime Alps contained about 50 per cent. of recent species.

I next re-visited Turin, and communicated to Signor Bonelli the result of my inquiries respecting the tertiary beds of the south of Italy, and of Sicily, upon which he kindly offered to review his fossils, some of which had been obtained from those countries, and to compare them with the Subapennine shells of northern Italy. He also promised to draw up immediately a list of the shells characteristic of the greensand of the Superga, and common to that locality and Bordeaux, that I might publish it at the end of my second volume; but the death of this amiable and zealous naturalist soon afterwards deprived me of the benefit of his assistance.

I had now fully decided on attempting to establish four sub-divisions of the great tertiary epoch, the same which are fully illustrated in the present work. I considered the basin of Paris and London to be the type of the first division; the beds of the Superga, of the second; the Subapennine strata of northern Italy,

of the third; and Ischia and the Val di Noto, of the fourth. I was also convinced that I had seen proofs, during my tour in Auvergne, Tuscany and Sicily, of volcanic rocks contemporaneous with the sedimentary strata of three of the above periods.

On my return to Paris, in February, 1829, I communicated to M. Desnoyers some of the new views to which my examination of Sicily had led me, and my intention to attempt a classification of the different tertiary formations in chronological order, by reference to the comparative proportion of living species of shells found fossil in each. He informed me, that during my tour he had been employed in printing the first part of his memoir, not yet published, 'on the Tertiary Formations more recent than the Paris basin,' in which he had insisted on the doctrine 'of the succession of tertiary formations of different ages.' At the end of the first part of his memoir, which was published before I left Paris\*, he annexed a note on the accordance of many of my views with his own, and my intention of arranging the tertiary formations chronologically, according to the relative number of fossils in each group, which were identifiable with species now living.

At the same time I learned from M. Desnoyers, that M. Deshayes had, by the mere inspection of the fossil shells in his extensive museum, convinced himself that the different tertiary formations might be

\* *Ann. des Sci. Nat.*, tome xvi. p. 214.

arranged in a chronological series. I accordingly lost no time in seeing M. Deshayes, who explained to me the data on which he considered that the three tertiary periods mentioned in the Tables, Appendix I., might be established. I at once perceived that the fossils obtained by me in my tour would form but an inconsiderable contribution to so great a body of zoological evidence as M. Deshayes had already in his possession. I therefore requested him to examine my shells when they arrived from Italy, and expressed my great desire to obtain his co-operation in my work, in which, as will appear in the sequel, I was fortunate enough to succeed.

The preparation of my first volume had now been suspended for nine months, and was not resumed until my return to London in the beginning of March, 1829. Before the whole was printed another summer arrived, and I again took the field to examine 'the Crag,' on the coasts of Essex, Norfolk, and Suffolk. The first volume appeared at length in January, 1830, after which I applied myself to perfect what I had written on 'the changes in the organic world,' a subject which merely occupied four or five chapters in my original sketch, but which was now expanded into a small treatise. Before this part was completed another summer overtook me, and I then set out on a geological expedition to the south of France, the Pyrenees, and Catalonia.

On my return to Paris, in September, 1830, I

studied for six weeks in the museum of M. Deshayes, examining his collection of fossil and recent shells, and profiting by his instructions in conchology. As he had not yet published any of the general results deducible from his valuable collection, I requested him to furnish me with lists of those species of shells which were common to two or more tertiary periods, as also the names of those known to occur both in some tertiary strata and in a living state. This he engaged to do, and we agreed that the information should be communicated in a tabular form. After several modifications of the plan first proposed for the Tables, we finally agreed upon the manner in which they should be constructed, and the execution was left entirely in the hands of M. Deshayes, in whose name they were to appear in my second volume.

The tables were sent to me in the course of the following spring (1831), and additions and corrections several months later. They contained not only the information which I had expected, but much more, for the names of several hundred species were added, as being common to two or more *formations* of the same *period*, whereas it was originally proposed to insert those only which were known to be common to two or more *distinct periods*. Thus, for example, more than 50 shells are now included in the tables, on the ground that they are common to the tertiary strata both of the London and Paris basins, although they

only occur in the *Eocene period* to which the strata of those basins belong. The names thus added will increase the value of the tables, and give a more complete view of the point to which fossil conchology has now reached; at the same time, it must be admitted that tables of shells cannot be perfected on this plan, as the science advances from year to year, without soon outgrowing the space which could reasonably be allotted to fossil conchology in a work on geology, for they would soon embrace the names of the greater number of known shells, nearly all of these being common to different groups of strata of the *same period*. Some of the catalogues which I have given in Appendix II., of fossil shells from the neighbourhood of the Red Sea, and from some other localities, may illustrate this remark, as they lead us to anticipate that, at no distant time, we may find a large proportion of all the *Recent* species in a fossil state.

In *treatises on fossil conchology*, such as I trust M. Deshayes will soon publish, we cannot have too complete a catalogue of all the species which have been found fossil in every locality, together with their synonyms; but in geological works we can only illustrate the more important theoretical points by catalogues of those shells which are either characteristic of particular periods, as being exclusively confined to them, or which show the connexion of two periods, by being common to each. For this purpose we

must select certain normal groups which do not approximate too closely to each other, and enumerate by name the species common to more than one of these. Thus, for example, we might omit in our tables the Newer Pliocene formations altogether, and enumerate the shells common to the Recent and Older Pliocene beds.

I have arranged the tertiary formations in four groups, as I had determined to do before I was acquainted with M. Deshayes; and in his tables he has referred the shells to three periods, according to which he had classed them before he had any communication with me. No confusion, however, will arise from this want of conformity between the tables and my classification, since I have named two of my periods (the Newer and Older Pliocene) as subdivisions of one of his; and by reference to the Synoptical Table, at p. 61, the reader will see which localities mentioned in M. Deshayes's Tables belong to the Newer and which to the Older Pliocene period.

In the summer of 1831 I made a geological excursion to the volcanic district of the Eifel, and on my return I determined to extend my work to three volumes, the second of which appeared in January, 1832. The last volume has been delayed till now by many interruptions, among which I may mention a tour, in the summer of 1832, up the valley of the Rhine, when I examined the loess (vol. iii. p. 151),

and a visit, on my way home through Switzerland, to the Valorsine, where I had an opportunity of verifying the observations of M. Necker on the granite veins and altered stratified rocks of that district. I may also mention the time occupied in the correction of the second edition of the first and second volumes, and the delivery of a course of Lectures in May and June, 1832, at King's College, London, on which occasion I had an opportunity of communicating to the scientific world a great part of the views now explained in my last volume.

*London, April, 1833.*

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# C O N T E N T S.

Vol. III.

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## CHAPTER I.

Connexion between the subjects treated of in the former parts of this work and those to be discussed in the present volume—Erroneous assumption of the earlier geologists respecting the discordance of the former and actual causes of change—Opposite system of inquiry adopted in this work—Illustrations from the history of the progress of Geology of the respective merits of the two systems—Habit of indulging conjectures respecting irregular and extraordinary agents not yet abandoned—Necessity in the present state of science of prefixing to a work on Geology treatises respecting the changes now in progress in the animate and inanimate world . . . . . 1

## CHAPTER II.

Arrangement of the materials composing the earth's crust—The existing continents chiefly composed of subaqueous deposits—Distinction between sedimentary and volcanic rocks—Between primary, secondary, and tertiary—Origin of the primary—Transition formations—Difference between secondary and tertiary strata—Discovery of tertiary groups of successive periods—Paris basin—London and Hampshire basins—Tertiary strata of Bordeaux, Piedmont, Touraine, &c.—Subapennine beds—English crag—More recent deposits of Sicily, &c. . . . . 8

## CHAPTER III.

Different circumstances under which the secondary and tertiary formations may have originated—Secondary series formed when the ocean prevailed: Tertiary during the conversion of sea into land, and the growth of a continent—Origin of interruption in the sequence of formations—The areas where new deposits take place are always varying—Causes which occasion this transference of the places of sedimentary deposition—Denudation augments the discordance in age of rocks in contact—Unconformability of overlying formations—In what manner the shifting of the areas of sedimentary deposition may combine with the gradual extinction and introduction of species to produce a series of deposits having distinct mineral and organic characters . . . . . 23

## CHAPTER IV.

PAGE

Chronological relations of mineral masses the first object in geological classification—Superposition, proof of more recent origin—Exceptions in regard to volcanic rocks—Relative age proved by included fragments of older rocks—Proofs of contemporaneous origin derived from mineral characters—Variations to which these characters are liable—Recurrence of distinct rocks at successive periods—Proofs of contemporaneous origin derived from organic remains—Zoological provinces are of limited extent, yet spread over wider areas than homogeneous mineral deposits—Different modes whereby dissimilar mineral masses and distinct groups of species may be proved to have been contemporaneous . . . . . 35

## CHAPTER V.

Classification of tertiary formations in chronological order—Comparative value of different classes of organic remains—Fossil remains of testacea the most important—Necessity of accurately determining species—Tables of shells by M. Deshayes—Four subdivisions of the Tertiary epoch—Recent formations—Newer Pliocene period—Older Pliocene period—Miocene period—Eocene period—The distinct zoological characters of these periods may not imply sudden changes in the animate creation—The recent strata form a common point of departure in distant regions—Numerical proportion of recent species of shells in different tertiary periods—Mammiferous remains of the successive tertiary eras—Synoptical Table of Recent and Tertiary formations . . . . . 45

## CHAPTER VI.

Newer Pliocene formations—Reasons for considering in the first place the more modern periods—Geological structure of Sicily—Formations of the Val di Noto of newer Pliocene period—Divisible into three groups—Great limestone—Schistose and arenaceous limestone—Blue marl with shells—Strata subjacent to the above—Volcanic rocks of the Val di Noto—Dikes—Tuffs and Peperinos—Volcanic conglomerates—Proofs of long intervals between volcanic eruptions—Dip and direction of newer Pliocene strata of Sicily . . . . . 62

## CHAPTER VII.

Marine and volcanic formations at the base of Etna—Their connexion with the strata of the Val di Noto—Bay of Trezza—Cyclopien isles—Fossil shells of recent species—Basalt and altered rocks in the Isle of Cyclops—

	PAGE
Submarine lavas of the bay of Trezza not currents from Etna—Internal structure of the cone of Etna—Val di Calanna—Val del Bove not an ancient crater—Its precipices intersected by countless dikes—Scenery of the Val del Bove—Form, composition, and origin of the dikes—Lavas and breccias intersected by them . . . . .	75

## CHAPTER VIII.

Speculations on the origin of the Val del Bove on Etna—Subsidences—Antiquity of the cone of Etna—Mode of computing the age of volcanos—Their growth analogous to that of exogenous trees—Period required for the production of the lateral cones of Etna—Whether signs of Diluvial Waves are observable on Etna . . . . .	95
---	----

## CHAPTER IX.

Origin of the newer Pliocene strata of Sicily—Growth of submarine formations gradual—Rise of the same above the level of the sea probably caused by subterranean lava—Igneous newer Pliocene rocks formed at great depths, exceed in volume the lavas of Etna—Probable structure of these recent subterranean rocks—Changes which they may have superinduced upon strata in contact—Alterations of the surface during and since the emergence of the newer Pliocene strata—Forms of the Sicilian valleys—Sea cliffs—Proofs of successive elevation—Why the valleys in the newer Pliocene districts correspond in form to those in regions of higher antiquity—Migrations of animals and plants since the emergence of the newer Pliocene strata—Some species older than the stations they inhabit—Recapitulation . . . . .	103
--	-----

## CHAPTER X.

Tertiary formations of Campania—Comparison of the recorded changes in this region with those commemorated by geological monuments—Differences in the composition of Somma and Vesuvius—Dikes of Somma, their origin—Cause of the parallelism of their opposite sides—Why coarser grained in the centre—Minor cones of the Phlegræan Fields—Age of the volcanic and associated rocks of Campania—Organic remains—External configuration of the country, how produced—No signs of diluvial waves—Marine Newer Pliocene strata visible only in countries of earthquakes—Illustrations from Chili—Peru—Parallel roads of Coquimbo—West-Indian archipelago—Honduras—East-Indian archipelago—Red Sea . . . . .	118
--	-----

## CHAPTER XI.

Newer Pliocene fresh-water formations—Valley of the Elsa—Travertins of Rome—Osseous breccias—Sicily—Caves near Palermo—Extinct animals	
--	--

	PAGE
in newer Pliocene breccias—Fossil bones of Marsupial animals in Australian caves—Formation of osseous breccias in the Morea—Newer Pliocene alluviums—Difference between alluviums and regular subaqueous strata—The former of various ages—Marine alluvium—Grooved surface of rocks—Erratic blocks of the Alps—Theory of deluges caused by paroxysmal elevations untenable—How ice may have contributed to transport large blocks from the Alps—European alluviums chiefly tertiary—Newer Pliocene in Sicily—Löss of the Valley of the Rhine—Its origin—Contains recent shells	137

## CHAPTER XII.

Geological monuments of the <i>older</i> Pliocene period—Subapennine formations—Opinions of Brocchi—Different groups termed by him Subapennine are not all of the same age—Mineral composition of the Subapennine formations—Marls—Yellow sand and gravel—Subapennine beds how formed—Illustration derived from the Upper Val d'Arno—Organic remains of Subapennine hills—Older Pliocene strata at the base of the Maritime Alps—Genoa—Savona—Albenga—Nice—Conglomerate of Valley of Magnan—Its origin—Tertiary strata at the eastern extremity of the Pyrenees	155
---	-----

## CHAPTER XIII.

Crag of Norfolk and Suffolk—Shown by its fossil contents to belong to the older Pliocene period—Heterogeneous in its composition—Superincumbent lacustrine deposits—Relative position of the crag—Forms of stratification—Strata composed of groups of oblique layers—Cause of this arrangement—Dislocations in the crag produced by subterranean movements—Protruded masses of chalk—Passage of marine crag into alluvium—Recent shells in a deposit at Sheppey, Ramsgate, and Brighton	171
--	-----

## CHAPTER XIV.

Volcanic rocks of the older Pliocene period—Italy—Volcanic region of Olot in Catalonia—Its extent and geological structure—Map—Number of cones—Scoriæ—Lava currents—Ravines in the latter cut by water—Ancient alluvium underlying lava—Jets of air called 'Bufadors'—Age of the Catalonian volcanos uncertain—Earthquake which destroyed Olot in 1421—Sardinian volcanos—District of the Eifel and Lower Rhine—Map—Geological structure of the country—Peculiar characteristics of the Eifel volcanos—Lake craters—Trass—Crater of the Roderberg—Age of the Eifel volcanic rocks uncertain—Brown coal formation	183
--	-----

## CHAPTER XV.

Miocene period—Marine formations—Faluns of Touraine—Comparison of the Faluns of the Loire and the English Crag—Basin of the Gironde and	
---	--

	PAGE
Landes—Fresh-water limestone of Saucats—Position of the limestone of Blaye—Eocene strata in the Bordeaux basin—Inland cliff near Dax—Strata of Piedmont—Superga—Valley of the Bormida—Molasse of Switzerland—Basin of Vienna—Styria—Hungary—Volhynia and Podolia—Montpellier	202

## CHAPTER XVI.

Miocene alluviums—Auvergne—Mont Perrier—Extinct quadrupeds—Velay—Orleanais—Alluviums contemporaneous with Faluns of Touraine—Miocene fresh-water formations—Upper Val d'Arno—Extinct mammalia—Coal of Cadibona—Miocene volcanic rocks—Hungary—Transylvania—Styria—Auvergne—Velay	217
--	-----

## CHAPTER XVII.

Eocene period—Fresh-water formations—Central France—Map—Limagne d'Auvergne—Sandstone and conglomerate—Tertiary Red marl and sandstone like the secondary 'new red sandstone'—Green and white foliated marls—Indusial limestone—Gypseous marls—General arrangement and origin of the Travertin—Fresh-water formation of the Limagne—Puy en Velay—Analogy of the strata to those of Auvergne—Cantal—Resemblance of Aurillac limestone and its flints to our upper chalk—Proofs of the gradual deposition of marl—Concluding remarks	225
---	-----

## CHAPTER XVIII.

Marine formations of the Eocene period—Strata of the Paris basin how far analogous to the lacustrine deposits of Central France—Geographical connexion of the Limagne d'Auvergne and the Paris basin—Chain of lakes in the Eocene period—Classification of groups in the Paris basin—Observations of M. C. Prevost—Sketch of the different subdivisions of the Paris basin—Contemporaneous marine and fresh-water strata—Abundance of <i>Cerithia</i> in the Calcaire grossier—Upper marine formation indicates a subsidence—Part of the Calcaire grossier destroyed when the upper marine strata originated—All the Parisian groups belong to one great epoch—Microscopic shells—Bones of quadrupeds in gypsum—In what manner entombed—Number of species—All extinct—Strata with and without organic remains alternating—Our knowledge of the physical geography, fauna, and flora of the Eocene period considerable—Concluding remarks	241
--	-----

## CHAPTER XIX.

Volcanic rocks of the Eocene period—Auvergne—Igneous formations associated with lacustrine strata—Hill of Gergovia—Eruptions in Central	
---	--

	PAGE
France at successive periods—Mont Dor an extinct volcano—Velay—Plomb du Cantal—Train of minor volcanos stretching from Auvergne to the Vivarais—Monts Domes—Puy de Côme—Puy Rouge—Ravines excavated through lava—Currents of lava at different heights—Subjacent alluviums of distinct ages—The more modern lavas of Central France may belong to the Miocene period—The integrity of the cones not inconsistent with this opinion—No eruptions during the historical era—Division of volcanos into ante-diluvian and post-diluvian inadmissible—Theories respecting the effects of the Flood considered—Hypothesis of a partial flood—Of a universal deluge—Theory of Dr. Buckland as controverted by Dr. Fleming—Recapitulation	257

## CHAPTER XX.

Eocene formations, <i>continued</i> —Basin of the Cotentin, or Valognes—Rennes—Basin of Belgium, or the Netherlands—Aix in Provence—Fossil insects—Tertiary strata of England—Basins of London and Hampshire—Different groups—Plastic clay and sand—London clay—Bagshot sand—Fresh-water strata of the Isle of Wight—Palæotherium and other fossil mammalia of Binstead—English Eocene strata conformable to chalk—Outliers on the elevated parts of the chalk—Inferences drawn from their occurrence—Sketch of a theory of the origin of the English tertiary strata	275
---	-----

## CHAPTER XXI.

Denudation of secondary strata during the deposition of the English Eocene formations—Valley of the Weald between the North and South Downs—Map—Secondary rocks of the Weald divisible into five groups—North and South Downs—Section across the valley of the Weald—Anticlinal axis—True scale of heights—Rise and denudation of the strata gradual—Chalk escarpments once sea-cliffs—Lower terrace of 'firestone,' how caused—Parallel ridges and valleys formed by harder and softer beds—No ruins of the chalk on the central district of the Weald—Explanation of this phenomenon—Double system of valleys, the longitudinal and the transverse—Transverse how formed—Gorges intersecting the chalk—Lewes Coomb—Transverse valley of the Adur	285
--	-----

## CHAPTER XXII.

Denudation of the Valley of the Weald, *continued*—The alternative of the proposition that the chalk of the North and South Downs were once continuous, considered—Dr. Buckland on the Valley of Kingsclere—Rise and denudation of secondary rocks gradual—Concomitant deposition of tertiary strata gradual—Composition of the latter such as would result from the wreck of the secondary rocks—Valleys and furrows on the chalk how caused

	PAGE
—Auvergne, the Paris basin, and south-east of England one region of earthquakes during the Eocene period—Why the central parts of the London and Hampshire basins rise nearly as high as the denudation of the Weald—Effects of protruding force counteracted by the levelling operations of water—Thickness of masses removed from the central ridge of the Weald—Great escarpment of the chalk having a direction north-east and south-west—Curved and vertical strata in the Isle of Wight—These were convulsed after the deposition of the fresh-water beds of Headen Hill—Elevations of land posterior to the crag—Why no Eocene alluviums recognizable—Concluding remarks on the intermittent operations of earthquakes in the south-east of England, and the gradual formation of valleys—Recapitulation	303

## CHAPTER XXIII.

Secondary formations—Brief enumeration of the principal groups—No species common to the secondary and tertiary rocks—Chasm between the Eocene and Maestricht beds—Duration of secondary periods—Former continents placed where it is now sea—Secondary fresh-water deposits why rare—Persistency of mineral composition why apparently greatest in older rocks—Supposed universality of red marl formations—Secondary rocks why more consolidated—Why more fractured and disturbed—Secondary volcanic rocks of many different ages	324
--	-----

## CHAPTER XXIV.

On the relative antiquity of different mountain-chains—Theory of M. Elie de Beaumont—His opinions controverted—His method of proving that different chains were raised at distinct periods—His proof that others were contemporaneous—His reasoning why not conclusive—His doctrine of the parallelism of contemporaneous lines of elevation—Objections—Theory of parallelism at variance with geological phenomena as exhibited in Great Britain—Objections of Mr. Conybeare—How far anticlinal lines formed at the same period are parallel—Difficulties in the way of determining the relative age of mountains	337
--	-----

## CHAPTER XXV.

On the rocks usually termed 'Primary'—Their relation to volcanic and sedimentary formations—The 'primary' class divisible into stratified and unstratified—Unstratified rocks called Plutonic—Granite veins—Their various forms and mineral composition—Proofs of their igneous origin—Granites of the same character produced at successive eras—Some of these newer than certain fossiliferous strata—Difficulty of determining the age of particular granites—Distinction between the volcanic and the plutonic rocks—Trappean rocks not separable from the volcanic—Passage from trap into granite—Theory of the origin of granite at every period from the earliest to the most recent	352
---	-----

## CHAPTER XXVI.

On the stratified rocks usually called 'primary'—Proofs from the disposition of their strata that they were originally deposited from water—Alteration of beds varying in composition and colour—Passage of gneiss into granite—Alteration of sedimentary strata by trappean and granitic dikes—Inference as to the origin of the strata called 'primary'—Conversion of argillaceous into hornblende schist—The term 'Hypogene' proposed as a substitute for primary—'Metamorphic' for 'stratified primary' rocks—No regular order of succession of hypogene formations—Passage from the metamorphic to the sedimentary strata—Cause of the high relative antiquity of the visible hypogene formations—That antiquity consistent with the hypothesis that they have been produced at each successive period in equal quantities—Great volume of hypogene rocks supposed to have been formed since the Eocene period—Concluding remarks . . . . . 365

---

Table I. Showing the relations of the various classes of rocks, the Alluvial, the Aqueous, the Volcanic, and the Hypogene, of different periods	386
Table II. Showing the order of superposition of the principal European groups of sedimentary strata mentioned in this work	389
Notes in explanation of the Tables of fossil shells in Appendix I.	395
Appendix I. Tables of fossil shells by Monsieur G. P. Deshayes	1
Appendix II. Lists of fossil Shells chiefly collected by the author in Sicily and Italy, named by M. Deshayes	53
Glossary, containing an explanation of geological and other scientific terms used in this work	61
Index	85

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## LIST OF PLATES AND WOOD-CUTS

IN THE THIRD VOLUME.

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### PLATES.

*Frontispiece.* View of the volcanos around Olot, in Catalonia. See p. 186. This view is taken from a sketch by the author; an attempt is made to represent by colours the different geological formations of which the country is composed. The blue line of mountains in the distance are the Pyrenees, which are to the north of the spectator, and consist of primary and ancient secondary rocks. In front of these are the secondary formations, described in chap. xiv., coloured purplish-grey of different tints, to express different distances. The flank of the hill, in the foreground, called Costa di Pujou, is composed partly of secondary rocks, which are seen to the left of a small bridle-road, and partly of volcanic, the red colour expressing lava and scorïæ.

Several very perfect volcanic cones, chiefly composed of red scorïæ, and having craters on their summits, are seen in the immediate neighbourhood of Olot, coloured red. The level plain on which that town stands has clearly been produced by the flowing down of many lava-streams from those hills into the bottom of a valley, probably once of considerable depth, like those of the surrounding country, but which has been in a great measure filled up by lava.

The reader should be informed, that in many impressions of this plate Montsacopa is mis-spelt 'Montescopa,' and Mount Garrinada is mis-spelt 'Gradenada.'

*Plate I.* The shells represented in this plate have been selected by M. Deshayes as characteristic of the Pliocene period of the Tables, Appendix I. The greater part of them are common both to the older and newer Pliocene periods of this work. Eight of the species, Nos. 1, 3, 5, 6, 7, 9, 13, and 14, are now living, but are given as being also found in the *Older* Pliocene formations. *Fusus crispus* is not found either *recent*

or in the Miocene or Eocene formations, but occurs both in the Newer and Older Pliocene strata. *Mitra plicatula* has been found only in the older Pliocene deposits. The *Turbo rugosus* was considered as exclusively Pliocene when selected by M. Deshayes, but M. Boué has since found it in the Miocene strata at Vienna and Moravia (see Tables, Appendix I. p. 26). *Buccinum semistriatum* is also a Miocene shell, but was inserted as being peculiarly abundant in the Pliocene strata.

*Plate II.* All the shells figured in this plate, except *Cardita Ajar*, are very characteristic of the Miocene formations; that is to say, they are found in that period and no other. *Cardita Ajar* is also very common in the Miocene strata, but is also a Recent species. It has not yet been observed in any *Pliocene* deposit.

*Plate III.* The species of shells figured in this plate are characteristic of the Eocene period, as being exclusively confined to deposits of that period, and for the most part abundant in them.

*Plate IV.* The microscopic shells of the order Cephalopoda, figured in this plate, are characteristic of the Eocene period, and are distinct from the microscopic shells of the Older Pliocene formations of Italy. The figures are from unpublished drawings by M. Deshayes, who has selected some of the most remarkable types of form. The reader will observe, that the minute points, figures 4, 8, 11, 14, and 18, indicate the natural size of the species which are represented. (For observations on these shells see p. 251.)

*Plate V.* Geological Map of the south-east of England, exhibiting the Denudation of the Weald. This map has been compiled in great part from Mr. Greenough's Geological Map of England, and Mr. Mantell's Map of the south-east of England. (Illustrations of Geol. of Sussex, and fossils of Tilgate Forest, 1827.) The eastern extremity of the 'denudation' is reduced from Mr. Murchison's Map of that district. (Geol. Trans., 2nd series, vol. ii. part i. plate 14.) The object of this map is fully explained in chapters xxi. and xxii. of this volume.

## LIST OF WOOD-CUTS.

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No.	Page
1. Diagram showing the order of succession of stratified masses . . . . .	15
2. Diagram showing the relative position of the Primary, Secondary, and Tertiary strata . . . . .	16
3. Diagram showing the relative age of the strata of the Paris basin, and those of the basin of the Loire, in Touraine . . . . .	20
4. Diagram showing the same in the strata of Suffolk and Piedmont . . . . .	21
5. Diagram containing sections in the Val di Noto, Sicily . . . . .	64
6. } Horizontal sections of dikes near Palagonia . . . . .	69
7. }	
8. Section of horizontal limestone in contact with inclined strata of Tuff in the hill of Novera, near Vizzini . . . . .	70
9. Section of calcareous grit and peperino, east of Palagonia, south side of the pass . . . . .	72
10. Section of the same beds on the north side of the pass . . . . .	72
11. Outline view of the cone of Etna from the summit of the limestone platform of Primosole . . . . .	75
12. Section from Paternò by Lago di Naftià to Palagonia . . . . .	76
13. Section of beds of clay and sand capped by columnar basalt and conglomerate at La Motta, near Catania . . . . .	77
14. View of the Isle of Cyclops, in the Bay of Trezza . . . . .	79
15. Diagram showing the contortions in the newer Pliocene strata of the Isle of Cyclops . . . . .	80
16. Horizontal section showing the invasion of the newer Pliocene strata of the Isle of Cyclops by lava . . . . .	81
17. Wood-cut showing the great valley on the east side of Etna . . . . .	83
18. Diagram explanatory of the origin of the Valleys of Calanna and St. Giacomo, on Etna . . . . .	86
19. View of dikes at the base of the Serre del Solfizio, Etna . . . . .	90
20. View of tortuous dikes or veins of lava, Punto di Guimento, Etna . . . . .	91
21. View of the rocks Finocchio, Capra, and Musara, in the Val del Bove . . . . .	92
22. View from the summit of Etna into the Val del Bove . . . . .	93
23. View of the Valley called Gozzo degli Martiri, below Melilli . . . . .	110
24. Diagram showing the manner of obliteration of successive lines of sea-cliff . . . . .	111
25. View of dikes or veins of lava at the Punto del Nasone, on Somma . . . . .	122
26. Diagram showing the superposition of alluvium and cave deposits containing <i>extinct</i> quadrupeds to a limestone containing <i>recent</i> shells . . . . .	139
27. Diagram showing the position of the Cave of San Ciro, near Palermo . . . . .	141
28. Diagram showing the position of Tertiary strata at Genoa . . . . .	166

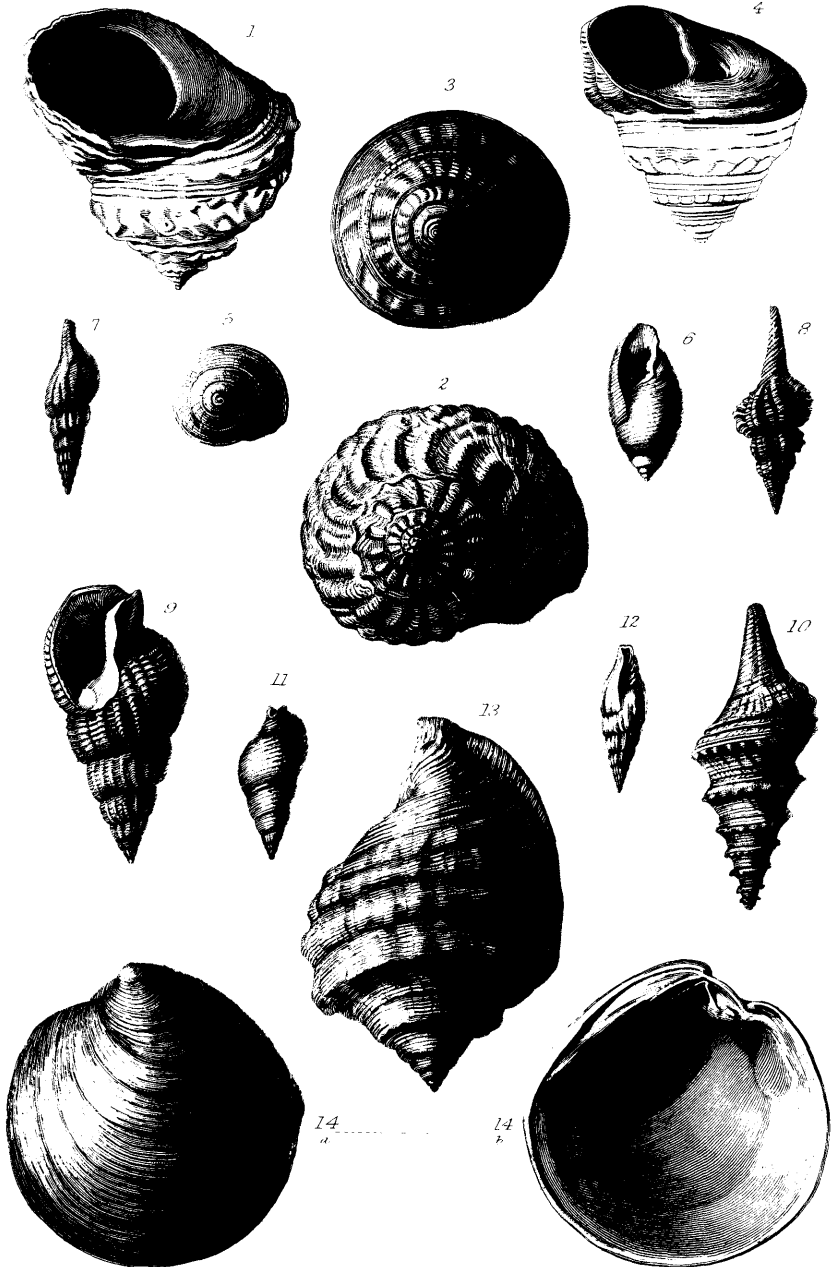
No.	Page
29. Section from Monte Calvo to the sea by the Valley of Magnan, near Nice . . . . .	167
30. Diagram showing the manner in which the Crag may be supposed to rest on the chalk . . . . .	173
31. Section of shelly crag near Walton, Suffolk . . . . .	174
32. Section at the light-house near Happisborough . . . . .	174
33. Section of Little Cat Cliff, showing the inclination of the layers of quartzose sand in opposite directions . . . . .	175
34. Lamination of shelly sand and loam, near the Signal-House, Walton . . . . .	175
35. Diagram illustrative of the successive deposition of strata . . . . .	176
36. Section of ripple marks caused by the wind on loose sand . . . . .	176
37. Bent strata of loam in the cliffs between Cromer and Runton . . . . .	178
38. Folding of the strata between East and West Runton . . . . .	178
39. Section in the cliffs east of Sherringham . . . . .	178
40. Section east of Sherringham, Norfolk . . . . .	179
41. Side view of a promontory of chalk and crag, at Trimmingham, Norfolk . . . . .	179
42. Northern protuberance of chalk, Trimmingham . . . . .	180
43. Map of the volcanic district of Catalonia . . . . .	184
44. Section of volcanic sand and ashes in a valley near Olot . . . . .	187
45. Section above the bridge of Cellent . . . . .	188
46. Section at Castell Folit . . . . .	190
47. Superposition of rocks in the volcanic district of Catalonia . . . . .	192
48. Map of the volcanic district of the Lower Rhine . . . . .	194
49. View of the Gemunden Maar . . . . .	195
50. Section of the same and other contiguous lake-craters . . . . .	196
51. Section of tertiary strata overlying chalk near Dax . . . . .	207
52. Section explaining the position of the Eocene strata in the Bordeaux basin . . . . .	209
53. Section of Inland cliff near Dax . . . . .	210
54. Position of the Miocene alluviums of Mont Perrier (or Boulade) . . . . .	217
55. Section of the fresh-water formation of Cadibona . . . . .	221
56. Map of Auvergne, Cantal, Velay, &c. . . . .	226
57. Section of Vertical marls near Clermont . . . . .	231
58. } Superposition of the formations of the Paris basin . . . . .	243
59. }	
60. Section of the Hill of Gergovia near Clermont . . . . .	259
61. Lavas of Auvergne resting on alluviums of different ages . . . . .	267
62. Map of the principal tertiary basins of the Eocene period . . . . .	275
63. Section from the London to the Hampshire basin across the Valley of the Weald . . . . .	288
64. Section of the country from the confines of the basin of London to that of Hants, with the principal heights above the level of the sea on a true scale . . . . .	288
65. View of the chalk escarpment of the South Downs, taken from the Devil's Dike, looking towards the west and south-west . . . . .	290

No.	Page
66. Chalk escarpment as seen from the hill above Steyning, Sussex. The castle and village of Bramber in the foreground . . .	291
67. Section of lower terrace of firestone . . . . .	292
68. Diagram explanatory of anticlinal and synclinal lines . . . . .	293
69. } Sections illustrating the gradual denudation of the Weald Valley	294, 295
70. }	
71. Section from the north escarpment of the South Downs to Barcombe . . . . .	296
72. Section of cliffs west of Sherringham . . . . .	297
73. View of the transverse valley of the Adur in the South Downs . . . . .	299
74. Supposed section of a transverse valley . . . . .	300
75. View of Lewes Coomb . . . . .	301
76. Section of a fault in the cliff-hills near Lewes . . . . .	301
77. Hypothetical section to illustrate the question of the denudation of the Weald Valley . . . . .	304
78. Ground plan of the Valley of Kingsclere . . . . .	305
79. Section across the Valley of Kingsclere from north to south . . . . .	305
80. Section of the Valley of Kingsclere with the heights on a true scale . . . . .	306
81. Hypothetical section illustrating the denudation of the Weald Valley and the contemporaneous origin of the Eocene strata . . . . .	310
82. } Diagrams illustrative of the relative antiquity of mountain-chains	340, 341
83. }	
84. Diagram showing the relative position of the Hypogene sedimentary and volcanic rocks . . . . .	353
85. Granite veins traversing stratified rocks . . . . .	354
86. Granite veins traversing gneiss at Cape Wrath in Scotland . . . . .	354
87. Granite veins passing through hornblende slate, Carnsilver Cove, Cornwall . . . . .	355
88. View of the junction of granite and limestone in Glen Tilt . . . . .	356
89. Lamination of clay-slate, Montagne de Seguinat, near Gavarnie, in the Pyrenees . . . . .	366
90. Junction of granite with jurassic or oolite strata in the Alps . . . . .	371
91. Diagram showing the different order of position in the Plutonic and Sedimentary formations of different ages . . . . .	388
92. Diagram to explain the meaning of the term ' <i>fault</i> ,' Glossary . . . . .	68
93. Diagram to explain the term ' <i>salient</i> angle,' Glossary . . . . .	79

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#### ERRATA.

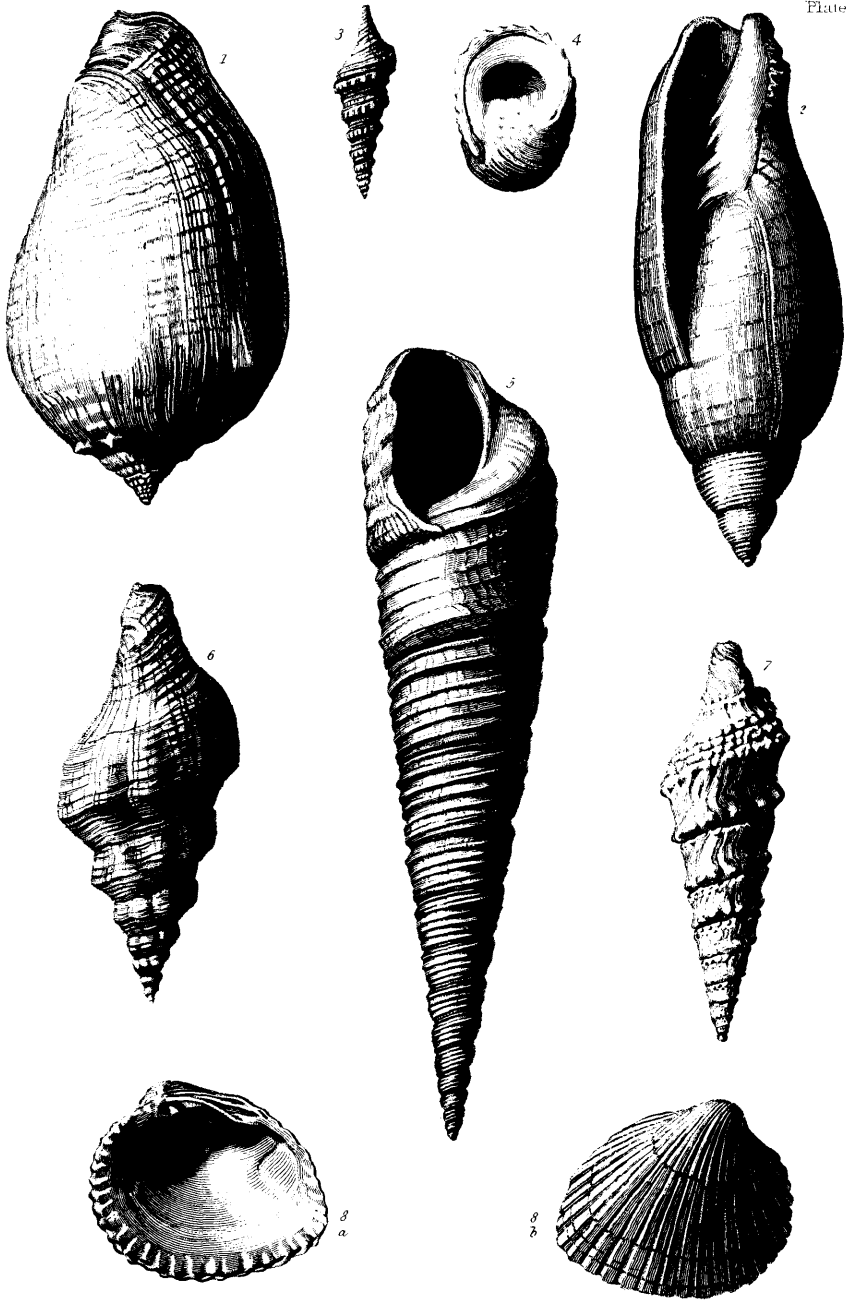
- Page 89, line 11 from the top, *for* vivid, *read* livid.  
— 103, line 10 from the top, *for* newer, *read* older.  
— 104, line 9 from the top, *for* Colosseum, *read* Coliseum.  
— 110, No. of wood-cut, *for* No. 22, *read* No. 23.  
— 111, Ditto, *for* No. 23, *read* No. 24.  
— 192, line 10 from the bottom, *for* with, *read* without.  
— 193, line 2 from the bottom, *for* Von Oyenhausen, *read* Von Oeynhausen.  
— 193, line 3 from the bottom, *for* M. Nöeggerath, *read* M. Noeggerath.  
— 197, line 19 from the top, *for* Moseberg, *read* Mosenberg.



1. 2. *Turbo rugosus* Lin. 3. 4. *Trochus magnus*, Lin. 5. *Solarium variegatum*, Lam.<sup>k</sup>  
 6. *Tornatella fasciata*, Lam.<sup>k</sup> 7. *Pleurotoma vulpecula*, Broc. 8. *Fusus crispus*, Bors.  
 9. *Bucanum prismaticum*, Bors. 10. *Pleurotoma rotata*, Broc. 11. *Bucanum semi-*  
*striatum* Broc. 12. *Mitra plicatula* Broc. 13. *Cypridaria echinophora* Lam.<sup>k</sup> 14. *Cytherea*  
*exoleta*, Lam.<sup>k</sup> var.







1. *Voluta rarispina*, Lam. — 2. *Mitra DuRenoi*, Bast. — 3. *Pleurotoma denticula*, Bast.  
 4. *Nerita Platensis*, Brong. — 5. *Turritella Proto*, Bast. — 6. *Fasciolaria turbinelloides*, Desh.  
 7. *Pleurotoma tuberculosa*, Bast. — 8. *A. b. Cavita*, Ajdr. Brug.



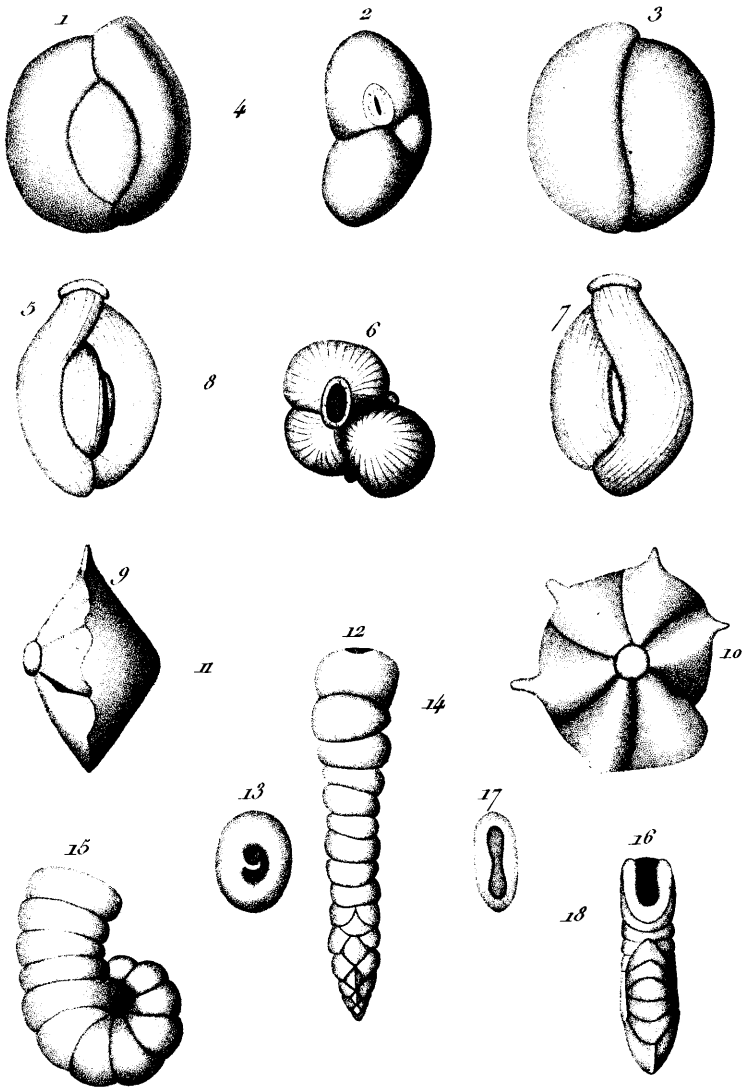


1. *Voluta costaria*. Lam<sup>k</sup>—2. *Pleurotoma clavicularis*.—3. *Cassidaria carinata*. Lam<sup>k</sup>  
 4. *Nerita tricarinata*. Lam<sup>k</sup>—5. *Calyptroæa trochiformis*. Lam<sup>k</sup>—6. *Turritella*  
*imbricataria*. Lam<sup>k</sup>—7. *Voluta digitalina*. Lam<sup>k</sup>—8. *Natica epiglottina*. Lam<sup>k</sup>  
 9. *Solarium canaliculatum*. Lam<sup>k</sup>—10. *Cardita planicosta*. Desh.

F. Oudart del.

T. Smith sc.





MICROSCOPIC FOSSIL SHELLS.

EOCENE TERTIARY PERIOD.

PARIS BASIN

1. 2. 3. 4. *Triloculina inflata*. Desh. — 5. 6. 7. 8. *Quinqueloculina striata*. Desh.  
 9. 10. 11. *Calcarina rarispina*. Desh. — 12. 13. 14. *Clavulina corrugata*. Desh.  
 15. 16. 17. 18. *Spirolina stenostoma*. Desh.





