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.

After the decline of the Roman empire, the cultivation of physical science was first revived with some success by the Saracens, about the middle of the eighth century of our era. The works of the most eminent classic writers were purchased at great expense from the Christians, and translated into Arabic; and Al Mamûn, son of the famous Harûn-al-Rashid, the contemporary of Charlemagne, received with marks of distinction, at his court at Bagdad, astronomers and men of learning from different countries. This caliph, and some of his successors, encountered much opposition and jealousy from the doctors of the Mahomedan law, who wished the Moslems to confine their studies to the Koran, dreading the effects of the diffusion of a taste for the physical sciences *. Almost all the works of the early Arabian writers are lost. Amongst those of the tenth century, of which fragments are now extant, is a system of mineralogy by Avicenna, a physician, in whose arrangement there is considerable merit. In the same century also, Omar, surnamed "El Aalem," or "the Learned," wrote a work on "the Retreat of the Sea." It appears that on comparing the charts of his own time with those made by the Indian and Persian astronomers two thousand years before, he had satisfied himself that important changes had taken place since the times of history in the form of the coasts of Asia, and that the extension of the sea had been greater at some former periods.

* Mod. Univ. Hist. vol. ii. chap. iv. section iii.

He was confirmed in this opinion by the numerous salt springs and marshes in the interior of Asia; a phenomenon from which Pallas, in more recent times, has drawn the same inference.

Von Hoff has suggested, with great probability, that the changes in the level of the Caspian, (some of which there is reason to believe have happened within the historical era,) and the geological appearances in that district, indicating the desertion by that sea of its ancient bed, had probably led Omar to his theory of a general subsidence. But whatever may have been the proofs relied on, his system was declared contradictory to certain passages in the Koran, and he was called upon publicly to recant his errors; to avoid which persecution he went into voluntary banishment from Samarkand *.

The cosmological opinions expressed in the Koran are few, and merely introduced incidentally; so that it is not easy to understand how they could have interfered so seriously with free discussion on the former changes of the globe. The Prophet declared that the earth was created in two days, and the mountains were then placed on it; and during these, and two additional days, the inhabitants of the earth were formed; and in two more the seven heavens †. There is no more detail of circumstances; and the deluge, which is also mentioned, is discussed with equal brevity. The waters are represented to have poured out of an oven; a strange fable, said to be borrowed from the Persian Magi, who represented them as issuing from the oven of an old woman ‡. All men were drowned, save Noah and his family; and then God said, "O earth, swallow up thy waters; and thou, O heaven, withhold thy rain;" and immediately the waters abated §.

* Von Hoff, Geschichte der Veränderungen der Erdoberfläche, vol. i. p. 406, who cites Delisle, bey Hissmann Welt-und Völkergeschichte. Alte Gesch. 1ter Theil. s. 234.—The Arabian persecutions for heretical dogmas in theology were often very sanguinary. In the same ages wherein learning was most in esteem, the Mahometans were divided into two sects, one of whom maintained that the Koran was increate, and had subsisted in the very essence of God from all eternity; and the other the Motazalites, who, admitting that the Koran was instituted by God, conceived it to have been first made when revealed to the Prophet at Mecca, and accused their opponents of believing in two eternal beings. The opinions of each of these sects were taken up by different caliphs in succession, and the followers of each sometimes submitted to be beheaded, or flogged till at the point of death, rather than renounce their creed.—Mod. Univ. Hist. vol. ii. chap. 4.

† Koran, chap. 41.

‡ Sale's Koran, chap. 11, see note. § Ibid.

We may suppose Omar to have represented the desertion of the land by the sea to have been gradual, and that his hypothesis required a greater lapse of ages than was consistent with Moslem orthodoxy; for it is to be inferred from the Koran, that man and this planet were created at the same time; and although Mahomet did not limit expressly the antiquity of the human race, yet he gave an implied sanction to the Mosaic chronology by the veneration expressed by him for the Hebrew Patriarchs*.

We must now pass over an interval of five centuries, wherein darkness enveloped almost every department of science, and buried in profound oblivion all prior investigations into the earth's history and structure. It was not till the earlier part of the sixteenth century that geological phenomena began to attract the attention of the Christian nations. At that period a very animated controversy sprung up in Italy, concerning the true nature and origin of marine shells, and other organized fossils, found abundantly in the strata of the peninsula†. The excavations made in 1517, for repairing the city of Verona, brought to light a multitude of curious petrifactions, and furnished matter for speculation to different authors, and among the rest to Fracastoro‡, who declared his opinion, that fossil shells had all belonged to living animals, which had formerly lived and multiplied, where their exuviæ are now found. He exposed the absurdity of having recourse to a certain "plastic force," which it was said had power to fashion stones into organic forms; and, with no less cogent arguments, demonstrated the futility of attributing the situation of the shells in question to the Mosaic deluge, a theory obstinately defended by some. That inundation, he observed, was too transient, it consisted principally of fluviatile waters; and, if it had transported shells to great distances, must have strewed them over the surface, not buried them at vast depths in the interior of mountains. His clear exposition of the

* Kossa, appointed master to the Caliph Al Mamûd, was author of a book, entitled, "The History of the Patriarchs and Prophets, *from the Creation of the World.*"—Mod. Univ. Hist. vol. ii. chap. 4.

† See Brocchi's Discourse on the Progress of the Study of Fossil Conchology in Italy, where some of the following notices on Italian writers will be found more at large.

‡ Museum Calceol.

evidence would have terminated the discussion for ever, if the passions of mankind had not been enlisted in the dispute; and even though doubts should for a time have remained in some minds, they would speedily have been removed by the fresh information obtained almost immediately afterwards, respecting the structure of fossil remains, and of their living analogues. But the clear and philosophical views of Fracastoro were disregarded, and the talent and argumentative powers of the learned were doomed for three centuries to be wasted in the discussion of these two simple and preliminary questions: first, whether fossil remains had ever belonged to living creatures; and, secondly, whether, if this be admitted, all the phenomena could be explained by the Noachian deluge. It had been the consistent belief of the Christian world, down to the period now under consideration, that the origin of this planet was not more remote than a few thousand years; and that since the creation the deluge was the only great catastrophe by which considerable change had been wrought on the earth's surface. On the other hand, the opinion was scarcely less general, that the final dissolution of our system was an event to be looked for at no distant period. The era, it is true, of the expected millennium had passed away; and for five hundred years after the fatal hour, when the annihilation of the planet had been looked for, the monks remained in undisturbed enjoyment of rich grants of land bequeathed to them by pious donors, who, in the preamble of deeds beginning "appropinquante mundi termino"—"appropinquante magno judicii die," left lasting monuments of the popular delusion.

But although in the sixteenth century it had become necessary to interpret the prophecies more liberally, and to assign a more distant date to the future conflagration of the world, we find, in the speculations of the early geologists, perpetual allusion to such an approaching catastrophe; while, in all that regarded the antiquity of the earth, no modification whatever of the opinions of the dark ages had been effected. Considerable alarm was at first excited when the attempt was made to

* In the monasteries of Sicily in particular, the title-deeds of many valuable grants of land are headed by such preambles, composed by the testators about the period when the good King Roger was expelling the Saracens from that island.

invalidate by physical proofs an article of faith so generally received, but there was sufficient spirit of toleration and candour amongst the Italian ecclesiastics, to allow the subject to be canvassed with much freedom. They entered warmly themselves into the controversy, often favouring different sides of the question; and however much we may deplore the loss of time and labour devoted to the defence of untenable positions, it must be conceded, that they displayed far less polemic bitterness than certain writers who followed them "beyond the Alps," two centuries and a half later.

The system of scholastic disputations encouraged in the Universities of the middle ages had unfortunately trained men to habits of indefinite argumentation, and they often preferred absurd and extravagant propositions, because greater skill was required to maintain them; the end and object of such intellectual combats being victory and not truth. No theory could be too far-fetched or fantastical not to attract some followers, provided it fell in with popular notions; and as cosmologists were not at all restricted, in building their systems, to the agency of known causes, the opponents of Fracastoro met his arguments by feigning imaginary causes, which differed from each other rather in name than in substance. Andrea Mattioli, for instance, an eminent botanist, the illustrator of Dioscorides, embraced the notion of Agricola, a German miner, that a certain "materia pinguis" or "fatty matter," set into fermentation by heat, gave birth to fossil organic shapes. Yet Mattioli had come to the conclusion from his own observations, that porous bodies, such as bones and shells, might be converted into stone, as being permeable to what he termed the "lapidifying juice." In like manner, Falloppio of Padua conceived that petrified shells had been generated by fermentation in the spots where they were found, or that they had in some cases acquired their form from "the tumultuous movements of terrestrial exhalations." Although not an unskilful professor of anatomy, he taught that certain tusks of elephants dug up in his time at Puglia were mere earthy concretions, and, consistently with these principles, he even went so far as to consider it not improbable, that the vases of Monte Testaceo at Rome were natural impressions stamped

in the soil.* In the same spirit, Mercati, who published, in 1574, faithful figures of the fossil shells preserved by Pope Sextus V. in the Museum of the Vatican, expressed an opinion that they were mere stones, which had assumed their peculiar configuration from the influence of the heavenly bodies; and Olivi of Cremona, who described the fossil remains of a rich Museum at Verona, was satisfied with considering them mere "sports of nature."

The title of a work of Cardano's, published in 1552, "De Subtilitate," (corresponding to what would now be called, Transcendental Philosophy,) would lead us to expect in the chapter on minerals, many far-fetched theories characteristic of that age; but, when treating of petrified shells, he decided that they clearly indicated the former sojourn of the sea upon the mountains†.

Some of the fanciful notions of those times were deemed less unreasonable, as being somewhat in harmony with the Aristotelian theory of spontaneous generation, then taught in all the schools. For men who had been instructed in early youth, that a large proportion of living animals and plants were formed from the fortuitous concourse of atoms, or had sprung from the corruption of organic matter, might easily persuade themselves, that organic shapes, often imperfectly preserved in the interior of solid rocks, owed their existence to causes equally obscure and mysterious.

But there were not wanting some, who at the close of this century expressed more sound and sober opinions. Cesalpino, a celebrated botanist, conceived that fossil shells had been left on the land by the retiring sea, and had concreted into stone during the consolidation of the soil‡; and in the following year (1597), Simeone Majoli§ went still further, and, coinciding for the most part with the views of Cesalpino, suggested that the shells and submarine matter of the Veronese, and other districts, might have been cast up, upon the land, by volcanic explosions, like those which gave rise, in 1588, to

* De Fossilib. p. 109 and 176.
† Brocchi, Con. Foss. Subap. Disc. sui Prog. vol. i. p. 5.
‡ De Metallicis. § Dies Caniculares.

Monte Nuovo, near Puzzuoli.—This hint was the first imperfect attempt to connect the position of fossil shells with the agency of volcanoes, a system afterwards more fully developed by Hooke, Lazzoro Moro, Hutton, and other writers.

Two years afterwards, Imperati advocated the animal origin of fossilized shells, yet admitted that stones could vegetate by force of "an internal principle;" and, as evidence of this, he referred to the teeth of fish, and spines of echini found petrified*.

Palissy, a French writer on "the Origin of Springs from Rain-water" and of other scientific works, undertook, in 1580, to combat the notions of many of his contemporaries in Italy, that petrified shells had all been deposited by the universal deluge. "He was the first," said Fontenelle, when, in the French Academy, he pronounced his eulogy more than fifty years afterwards, "who dared assert" in Paris, that fossil remains of testacea and fish had once belonged to marine animals.

To enumerate the multitude of Italian writers, who advanced various hypotheses, all equally fantastical, in the early part of the seventeenth century, would be unprofitably tedious, but Fabio Colonna deserves to be distinguished; for, although he gave way to the dogma, that all fossil remains were to be referred to the Noachian deluge, he resisted tne absurd theory of Stelluti, who taught that fossil wood and ammonites were mere clay, altered into such forms by sulphureous waters and subterranean heat; and he pointed out the different states of shells buried in the strata, distinguishing between, first, the mere mould or impression; secondly, the cast or nucleus; and thirdly, the remains of the shell itself. He had also the merit of being the first to point out, that some of the fossils had belonged to marine, and some to terrestrial testacea†. But the most remarkable work of that period was published by Steno, a Dane, once professor of anatomy at Padua, and who afterwards resided many years at the court of the Grand Duke of Tuscany. The treatise bears the quaint title of "De Solido intra Solidum contento naturaliter, (1669,)" by which the author intended to express "On Gems, Crystals, and organic Petrifactions inclosed within solid Rocks." This work

* Storia Naturale. † Osserv. sugli Animali aquat. e terrest. 1626.

attests the priority of the Italian school in geological research; exemplifying at the same time the powerful obstacles opposed, in that age, to the general reception of enlarged views in the science. Steno had compared the fossil shells with their recent analogues, and traced the various gradations from the state of mere calcination, when their natural gluten only was lost, to the perfect substitution of stony matter. He demonstrated that many fossil teeth found in Tuscany belonged to a species of shark; and he dissected, for the purpose of comparison, one of these fish recently taken from the Mediterranean. That the remains of shells and marine animals found petrified were not of animal origin was still a favourite dogma of many who were unwilling to believe, that the earth could have been inhabited by living beings, long before many of the mountains were formed. By way of compromise, as it were, for dissenting from this opinion, Steno conceded, as Fabio Colonna had done before him, that all marine fossils might have been transported into their present situation at the time of the Noachian deluge. He maintained that fossil vegetables had been once living plants, and he hinted that they might, in some instances, indicate the distinction between fluviatile and marine deposits. He also inferred that the present mountains had not existed ever since the origin of things, suggesting that many strata of submarine origin had been accumulated in the interval between the creation and deluge. Here he displayed his great anxiety to reconcile his theory with the Scriptures; for he at the same time advanced an opinion, which does not seem very consistent with such a doctrine, *viz.* that there was a wide distinction between the shelly, and nearly horizontal beds at the foot of the Apennines, and the older mountains of highly inclined stratification. Both, he observed, were of sedimentary origin; and a considerable interval of time must have separated their formation. Tuscany, according to him, had successively past *through six different states;* and to explain these mighty changes, he called in the agency of inundations, earthquakes, and subterranean fires.

His generalizations were for the most part comprehensive and just; but such was his awe of popular prejudice, that he only ventured to throw them out as mere conjectures, and the

timid reserve of his expressions must have raised doubts as to his own confidence in his opinions, and deprived them of some of the authority due to them.

Scilla, a Sicilian painter, published, in 1670, a work on the fossils of Calabria, illustrated by good engravings. This was written in Latin, with great spirit and elegance, and it proves the continued ascendancy of dogmas often refuted; for we find the wit and eloquence of the author chiefly directed against the obstinate incredulity of naturalists, as to the organic nature of fossil shells*. Like many eminent naturalists of his day, Scilla gave way to the popular persuasion that all fossil shells were the effects and proofs of the Mosaic deluge. It may be doubted whether he was perfectly sincere, and some of his contemporaries who took the same course were certainly not so. But so eager were they to root out what they justly considered an absurd prejudice respecting the nature of organized fossils, that they seem to have been ready to make any concessions, in order to establish this preliminary point. Such a compromising policy was short-sighted, since it was to little purpose that the nature of the documents should at length be correctly understood, if men were to be prevented from deducing fair conclusions from them.

The theologians who now entered the field in Italy, Germany, France and England, were innumerable; and henceforward, they who refused to subscribe to the position, that all marine organic remains were proofs of the Mosaic deluge, were exposed to the imputation of disbelieving the whole of the sacred writings. Scarcely any step had been made in approximating to sound theories since the time of Fracastoro, more than a hundred years having been lost, in writing down the dogma that organized fossils were mere sports of nature. An additional period of a century and a half was now destined to be consumed in exploding the hypothesis, that organized fossils had all been buried in the solid strata, by the Noachian flood. Never did a theoretical fallacy, in any branch of science,

* Scilla quotes the remark of Cicero on the story that a stone in Chios had been cleft open, and presented the head of Paniscus in relief—"I believe," said the orator, "that the figure bore some resemblance to Paniscus, but not such that you would have deemed it sculptured by Scopas, for chance never perfectly imitates the truth."

interfere more seriously with accurate observation and the systematic classification of facts. In recent times, we may attribute our rapid progress chiefly to the careful determination of the order of succession in mineral masses, by means of their different organic contents, and their regular superposition. But the old diluvialists were induced by their system to confound all the groups of strata together instead of discriminating,—to refer all appearances to one cause and to one brief period, not to a variety of causes acting throughout a long succession of epochs. They saw the phenomena only as they desired to see them, sometimes misrepresenting facts, and at other times deducing false conclusions from correct data. Under the influence of such prejudices, three centuries were of as little avail, as the same number of years in our own times, when we are no longer required to propel the vessel against the force of an adverse current.

It may be well to forewarn our readers, that in tracing the history of geology from the close of the seventeenth to the end of the eighteenth century, they must expect to be occupied with accounts of the retardation, as well as of the advance of the science. It will be our irksome task to point out the frequent revival of exploded errors, and the relapse from sound to the most absurd opinions. It will be necessary to dwell on futile reasoning and visionary hypothesis, because the most extravagant systems were often invented or controverted by men of acknowledged talent. A sketch of the progress of Geology is the history of a constant and violent struggle between new opinions and ancient doctrines, sanctioned by the implicit faith of many generations, and supposed to rest on scriptural authority. The inquiry, therefore, although highly interesting to one who studies the philosophy of the human mind, is singularly barren of instruction to him who searches for truths in physical science.

Quirini, in 1676 *, contended, in opposition to Scilla, that the diluvian waters could not have conveyed heavy bodies to the summit of mountains, since the agitation of the sea never (as Boyle had demonstrated) extended to great depths†, and

* De Testaceis fossilibus Mus. Septaliani.

† The opinions of Boyle, alluded to by Quirini, were published a few years

still less could the testacea, as some pretended, have lived in these diluvial waters, for "the duration of the flood was brief, and *the heavy rains must have destroyed the saltness of the sea!*" He was the first writer who ventured to maintain that the universality of the Noachian cataclysm ought not to be insisted upon. As to the nature of petrified shells, he conceived that as earthy particles united in the sea to form the shells of mollusca, the same crystallizing process might be effected on the land, and that, in the latter case, the germs of the animals might have been disseminated through the substance of the rocks, and afterwards developed by virtue of humidity. Visionary as was this doctrine, it gained many proselytes even amongst the more sober reasoners of Italy and Germany, for it conceded both that fossil bodies were organic, and that the diluvial theory could not account for them.

In the mean time, the doctrine that fossil shells had never belonged to real animals, maintained its ground in England, where the agitation of the question began at a much later period. Dr. Plot, in his "Natural History of Oxfordshire," (1677,) attributed to "a plastic virtue latent in the earth" the origin of fossil shells and fishes; and Lister, to his accurate account of British shells, in 1678, added the fossil species, under the appellation of *turbinated and bivalve stones*. "Either," said he, "these were terriginous, or, if otherwise, the animals they so exactly represent *have become extinct*." This writer appears to have been the first who was aware of the continuity over large districts of the principal groups of strata in the British series, and who proposed the construction of regular geological maps.

The "Posthumous Works of Robert Hooke, M.D.," well known as a great mathematician and natural philosopher,

before, in a short article entitled "On the bottom of the Sea." From observations collected from the divers of the pearl fishery, Boyle had ascertained that when the waves were six or seven feet high above the surface of the water, there were no signs of agitation at the depth of fifteen fathoms; and that even during heavy gales of wind, the motion of the water was exceedingly diminished at the depth of twelve or fifteen feet. He had also learnt from some of his informants, that there were currents running in opposite directions at different depths.—Boyle's Works, vol. iii. p. 110. London, 1744. The reader will see, in our chapter on "Marine Currents," that Boyle's doctrine must be received with some modification.

appeared in 1705, containing, "A Discourse of Earthquakes," which, we are informed by his editor, was written in 1668, but revised at subsequent periods*. Hooke frequently refers to the best Italian and English authors who wrote before his time on geological subjects; but there are no passages in his works implying that he participated in the enlarged views of Steno and Lister, or of his contemporary Woodward, in regard to the geographical extent of certain groups of strata. His treatise, however, is the most philosophical production of that age, in regard to the causes of former changes in the organic and inorganic kingdoms of nature.

"However trivial a thing," he says, "a rotten shell may appear to some, yet these monuments of nature are more certain tokens of antiquity than coins or medals, since the best of those may be counterfeited or made by art and design, as may also books, manuscripts, and inscriptions, as all the learned are now sufficiently satisfied has often been actually practised," &c.; "and though it must be granted that it is very difficult to read them (the records of nature) and *to raise a chronology out of them*, and to state the intervals of the time wherein such or such catastrophes and mutations have happened, yet it is not impossible," &c.† Respecting the extinction of species, Hooke was aware that the fossil ammonites, nautili, and many other shells and fossil skeletons found in England, were of different species from any then known; but he doubted whether the species had become extinct, observing that the knowledge of naturalists of all the marine species, especially those inhabiting the deep sea, was very deficient. In some parts of his writings, however, he leans to the opinion that species had been lost; and, in speculating on this subject, he even suggests that there might be some connection between the disappearance of certain kinds of animals and plants, and the changes wrought by earthquakes in former ages: for some species, he observes with great sagacity, are "*peculiar to certain places*, and not to be found elsewhere. If, then, such a place had been swallowed up, it is not improbable but that those animate beings may

* Between the year 1688 and his death, in 1703, he read several memoirs to the Royal Society, and delivered lectures on various subjects, relating to fossil remains and the effects of earthquakes.

† Post. Works, Lecture Feb. 29, 1688.

have been destroyed with it; and this may be true both of aërial and aquatic animals: for those animated bodies, whether vegetables or animals, which were naturally nourished or refreshed by the air, would be destroyed by the water*," &c. Turtles, he adds, and such large ammonites as are found in Portland, seem to have been the productions of the seas of hotter countries, and *it is necessary to suppose that England once lay under the sea within the torrid zone!* To explain this and similar phenomena, he indulges in a variety of speculations concerning changes in the position of the axis of the earth's rotation, a shifting of the earth's centre of gravity, "*analogous to the revolutions of the magnetic pole*," &c. None of these conjectures, however, are proposed dogmatically, but rather in the hope of promoting fresh inquiries and experiments.

In opposition to the prejudices of his age, we find him arguing that nature had not formed fossil bodies, "for no other end than to play the mimic in the mineral kingdom"—that figured stones were "really the several bodies they represent, or the mouldings of them petrified," and "not, as some have imagined, a 'lusus naturæ,' sporting herself in the needless formation of useless beings †."

It was objected to Hooke, that his doctrine of the extinction of species derogated from the wisdom and power of the Omnipotent Creator; but he answered, that, as individuals die, there may be some termination to the duration of a species; and his opinions, he declared, were not repugnant to Holy Writ: for the Scriptures taught that our system was dege-

* Posth. Works, p. 327.

† Posth. Works, Lecture Feb. 15, 1688. Hooke explained, with considerable clearness, the different modes wherein organic substances may become lapidified; and, among other illustrations, he mentions some silicified palm-wood brought from Africa, on which M. de la Hire had read a memoir to the Royal Academy of France, (June, 1692,) wherein he had pointed out not only the tubes running the length of the trunk, but the roots at one extremity. De la Hire, says Hooke, also treated of certain trees found petrified in "the river that passes by Bakan, in the kingdom of *Ava*, and which has for the space of ten leagues the virtue of petrifying wood." It is an interesting fact, that the silicified wood of the Irawadi should have attracted attention more than one hundred years ago. Remarkable discoveries have been recently made there of fossil animals and vegetables by Mr. Crawfurd and Dr. Wallich.—See Geol. Trans. vol. ii. part 3, p. 377, Second Series. De la Hire cites Father Duchatz, in the second volume of "Observations made in the Indies by the Jesuits."

nerating, and tending to its final dissolution; "and as, when that shall happen, all the species will be lost, why not some at one time and some at another *?"

But his principal object was to account for the manner in which shells had been conveyed into the higher parts of "the Alps, Apennines, and Pyrenean hills, and the interior of continents in general." These and other appearances, he said, might have been brought about by earthquakes, "which have turned plains into mountains, and mountains into plains, seas into land, and land into seas, made rivers where there were none before, and swallowed up others that formerly were, &c. &c.; and which, since the creation of the world, have wrought many great changes on the superficial parts of the earth, and have been the instruments of placing shells, bones, plants, fishes, and the like, in those places, where, with much astonishment, we find them †." This doctrine, it is true, had been laid down in terms almost equally explicit by Strabo, to explain the occurrence of fossil shells in the interior of continents, and to that geographer, and other writers of antiquity, Hooke frequently refers; but the revival and developement of the system was an important step in the progress of modern science.

He enumerated all the examples known to him of subterranean disturbance, from "the sad catastrophe of Sodom and Gomorrah" down to the Chilian earthquake of 1646. The elevating of the bottom of the sea, the sinking and submersion of the land, and most of the inequalities of the earth's surface, might, he said, be accounted for by the agency of these subterranean causes. He mentions that the coast near Naples was raised during the eruption of Monte Nuovo; and that, in 1591, land rose in the island of St. Michael, during an eruption; and although it would be more difficult, he says, to prove, he does not doubt but that there had been *as many earthquakes in the parts of the earth under the ocean, as in the parts of the dry land;* in confirmation of which he mentions the immeasurable depth of the sea near some volcanoes. To attest the extent of simultaneous subterranean movements, he refers to an earthquake in the West Indies, in 1690, where

* Posth. Works, Lecture May 29, 1689. † Posth. Works, p. 312.

the space of earth raised, or "struck upwards" by the shock, exceeded the length of the Alps or the Pyrenees.

As Hooke declared the favourite hypothesis of the day ("that marine fossil bodies were to be referred to Noah's flood") to be wholly untenable, he appears to have felt himself called upon to substitute a diluvial theory of his own, and thus he became involved in countless difficulties and contradictions. "During the great catastrophe," he said, "there might have been a changing of that part which was before dry land into sea by sinking, and of that which was sea into dry land by raising, and marine bodies might have been buried in sediment beneath the ocean, in the interval between the creation and the deluge *." Then followed a disquisition on the separation of the land from the waters, mentioned in Genesis: during which operation some places of the shell of the earth were forced outwards, and others pressed downwards or inwards, &c. His diluvial hypothesis very much resembled that of Steno, and was entirely opposed to the fundamental principles professed by him, that he would explain the former changes of the earth *in a more natural manner* than others had done. When, in despite of this declaration, he required a former "crisis of nature," and taught that earthquakes had become debilitated, and that the Alp, Andes, and other chains, had been lifted up in a few months, his machinery was as extravagant and visionary as that of his most fanciful predecessors; and for this reason, perhaps, his whole theory of earthquakes met with very undeserved neglect.

One of his contemporaries, the celebrated naturalist, Ray, participated in the same desire to explain geological phenomena, by reference to causes less hypothetical than those usually resorted to †. In his Essay on "Chaos and Creation" he proposed a system, agreeing in its outline, and in many of its details, with that of Hooke; but his knowledge of natural history enabled him to elucidate the subject with various original observations. Earthquakes, he suggested, might have

* Posth. Works, p. 410.

† Ray's Physico-theological Discourses were of somewhat later date than Hooke's great work on earthquakes. He speaks of Hooke as one "whom for his learning and deep insight into the mysteries of nature he deservedly honoured.' —*On the Deluge*, chap. 4.

been the second causes employed at the creation, in separating the land from the waters, and in gathering the waters together into one place. He mentions, like Hooke, the earthquake of 1646, which had violently shaken the Andes for some hundreds of leagues, and made many alterations therein. In assigning a cause for the general deluge, he preferred a change in the earth's centre of gravity to the introduction of earthquakes. Some unknown cause, he said, might have forced the subterranean waters outwards, as was, perhaps, indicated by "the breaking up of the fountains of the great deep."

Ray was one of the first of our writers who enlarged upon the effects of running water upon the land, and of the encroachment of the sea upon the shores. So important did he consider the agency of these causes, that he saw in them an indication of the tendency of our system to its final dissolution; and he wondered why the earth did not proceed more rapidly towards a general submersion beneath the sea, when so much matter was carried down by rivers, or undermined in the sea-cliffs. We perceive clearly from his writings, that the gradual decline of our system, and its future consummation by fire, was held to be as necessary an article of faith by the orthodox, as was the recent origin of our planet. His Discourses, like those of Hooke, are highly interesting, as attesting the familiar association in the minds of philosophers, in the age of Newton, of questions in physics and divinity. Ray gave an unequivocal proof of the sincerity of his mind, by sacrificing his preferment in the church, rather than take an oath against the Covenanters, which he could not reconcile with his conscience. His reputation, moreover, in the scientific world placed him high above the temptation of courting popularity, by pandering to the physico-theological taste of his age. It is, therefore, curious to meet with so many citations from the Christian fathers and prophets in his essays on physical science—to find him in one page proceeding by the strict rules of induction, to explain the former changes of the globe, and in the next gravely entertaining the question, whether the sun and stars, and the whole heavens shall be annihilated, together with the earth, at the era of the grand conflagration.

Among the contemporaries of Hooke and Ray, Woodward, a professor of medicine, had acquired the most extensive infor-

mation respecting the geological structure of the crust of the earth. He had examined many parts of the British strata with minute attention; and his systematic collection of specimens, bequeathed to the University of Cambridge, and still preserved there as arranged by him, shews how far he had advanced in ascertaining the order of superposition. From the great number of facts collected by him we might have expected his theoretical views to be more sound and enlarged than those of his contemporaries; but in his anxiety to accommodate all observed phenomena to the scriptural account of the Creation and Deluge, he arrived at most erroneous results. He conceived "the whole terrestrial globe to have been taken to pieces and dissolved at the flood, and the strata to have settled down from this promiscuous mass as any earthy sediment from a fluid *." In corroboration of these views, he insisted upon the fact, that "marine bodies are lodged in the strata according to the order of their gravity, the heavier shells in stone, the lighter in chalk, and so of the rest †." Ray immediately exposed the unfounded nature of this assertion, remarking truly, that fossil bodies "are often mingled, heavy with light, in the same stratum;" and he even went so far as to say, that Woodward "must have invented the phenomena for the sake of confirming his bold and strange hypothesis ‡"—a strong expression from the pen of a contemporary.

At the same time Burnet published his "Theory of the Earth §." The title is most characteristic of the age,—"The Sacred Theory of the Earth, containing an Account of the Original of the Earth, and of all the general Changes which it hath already undergone, or is to undergo, till the Consummation of all Things." Even Milton had scarcely ventured in his poem to indulge his imagination so freely in painting scenes of the Creation and Deluge, Paradise and Chaos, as this writer, who set forth pretensions to profound philosophy. He explained why the primeval earth enjoyed a perpetual spring before the flood! shewed how the crust of the globe was fissured by "the sun's rays," so that it burst, and thus the dilu-

* Essay towards a Natural History of the Earth, 1695. Preface.

† Ibid. Preface.

‡ Consequences of the Deluge, p. 165.

§ First published in Latin, between the years 1680 and 1690.

vial waters were let loose from a supposed central abyss. Not satisfied with these themes, he derived from the books of the inspired writers, and even from heathen authorities, prophetic views of the future revolutions of the globe, gave a most terrific description of the general conflagration, and proved that a new heaven and a new earth will rise out of a *second chaos*—after which will follow the blessed millennium.

The reader should be informed, that according to the opinion of many respectable writers of that age, there was good scriptural ground for presuming that the garden bestowed upon our first parents was not on the earth itself, but above the clouds, in the middle region between our planet and the moon. Burnet approaches with becoming gravity the discussion of so important a topic. He was willing to concede that the geographical position of Paradise was not in Mesopotamia, yet he maintained that it was upon the earth, and in the southern hemisphere, near the equinoctial line. Butler selected this conceit as a fair mark for his satire, when, amongst the numerous accomplishments of Hudibras, he says—

> He knew the seat of Paradise,
> Could tell in what degree it lies;
> And as he was disposed, could prove it
> Below the moon, or else above it.

Yet the same monarch, who is said never to have slept without Butler's poem under his pillow, was so great an admirer and patron of Burnet's book, that he ordered it to be translated from the Latin into English. The style of the "Sacred Theory" was eloquent, and displayed powers of invention of no ordinary stamp. It was, in fact, a fine historical romance, as Buffon afterwards declared; but it was treated as a work of profound science in the time of its author, and was panegyrized by Addison in a Latin ode, while Steele praised it in the "Spectator," and Warton, in his "Essay on Pope," discovered that Burnet united the faculty of *judgment* with powers of imagination.

Another production of the same school, and equally characteristic of the times, was that of Whiston, entitled, "A New Theory of the Earth, wherein the Creation of the World in six Days, the Universal Deluge, and the General Conflagration, as laid down in the Holy Scriptures, are shewn to be perfectly

agreeable to Reason and Philosophy." He was at first a follower of Burnet, but his faith in the infallibility of that writer was shaken by the declared opinion of Newton, that there was every presumption in astronomy against any former change in the inclination of the earth's axis. This was a leading dogma in Burnet's system, though not original, for it was borrowed from an Italian, Alessandro degli Alessandri, who had suggested it in the beginning of the fifteenth century, to account for the former occupation of the present continents by the sea. La Place has since strengthened the arguments of Newton, against the probability of any former revolution of this kind. The remarkable comet of 1680 was fresh in the memory of every one, when Whiston first began his cosmological studies, and the principal novelty of his speculations consisted in attributing the deluge to the near approach to the earth of one of these erratic bodies. Having ascribed an increase of the waters to this source, he adopted Woodward's theory, supposing all stratified deposits to have resulted from the "chaotic sediment of the flood." Whiston was one of the first who ventured to propose that the text of Genesis should be interpreted differently from its ordinary acceptation, so that the doctrine of the earth having existed long previous to the creation of man might no longer be regarded as unorthodox. He had the art to throw an air of plausibility over the most improbable parts of his theory, and seemed to be proceeding in the most sober manner, and by the aid of mathematical demonstration, to the establishment of his various propositions. Locke pronounced a panegyric on his theory, commending him for having explained so many wonderful and before inexplicable things. His book, as well as Burnet's, was attacked and refuted by Keill*. Like all who introduced purely hypothetical causes to account for natural phenomena, he retarded the progress of truth, diverting men from the investigation of the laws of sublunary nature, and inducing them to waste time in speculations on the power of comets to drag the waters of the ocean over the land—on the condensation of the vapours of their tails into water, and other matters equally edifying.

John Hutchinson, who had been employed by Woodward

* An Examination of Dr. Burnet's Theory, &c. 2d edition, 1734.

in making his collection of fossils, published afterwards, in 1724, the first part of his "Moses's Principia," wherein he ridiculed Woodward's hypothesis. He and his numerous followers were accustomed to declaim loudly against human learning, and they maintained that the Hebrew scriptures, when rightly translated, comprised a perfect system of natural philosophy, for which reason they objected to the Newtonian theory of gravitation.

Leibnitz, the great mathematician, published his "Protogæa" in 1680. He imagined this planet to have been originally a burning luminous mass, and that ever since its creation it has been undergoing gradual refrigeration. Nearly all the matter of the earth was at first encompassed by fire. When the outer crust had at length cooled down sufficiently to allow the vapours to be condensed, they fell and formed a universal ocean, investing the globe, and covering the loftiest mountains. Further consolidation produced rents, vacuities, and subterranean caverns, and the ocean, rushing in to fill them, was gradually lowered. The principal feature of this theory, the gradual diminution of the original heat, and of an ancient universal ocean, were adopted by Buffon and De Luc, and entered, under different modifications, into a great number of succeeding systems.

Andrea Celsius, the Swedish astronomer, published, about this time, his remarks on the gradual diminution of the waters in the Baltic, which sea, he imagined, had been sinking from time immemorial at the rate of forty-five inches in a century. His opinions gave rise to a controversy which has lasted even to our own days, and to which we are indebted for correct observations of a variety of facts concerning the gradual filling up of the Baltic by fluviatile and marine sediment. Linnæus * favoured the views of Celsius, because they fell in with his own notions concerning a Paradise, where all the animals were created, and from whence they passed into all other parts of the earth, as these became dry in succession.

In Germany, in the mean time, Scheuchzer laboured to prove, in a work entitled the "Complaint of the Fishes," (1708,) that the earth had been remodelled at the deluge.

* De Telluris habitabilis Incremento, 1743.

Pluche also, in 1732, wrote to the same effect, while Holbach, in 1753, after considering the various attempts to refer all the ancient formations to the Noachian flood, exposed the insufficiency of the cause.

We return with pleasure to the geologists of Italy, who preceded, as we before saw, the naturalists of other countries in their investigations into the ancient history of the earth, and who still maintained a decided pre-eminence. They refuted and ridiculed the physico-theological systems of Burnet, Whiston, and Woodward*, while Vallisneri †, in his comments on the Woodwardian theory, remarked how much the interests of religion as well as those of sound philosophy had suffered, by perpetually mixing up the sacred writings with questions in physical science. The works of this author were rich in original observations. He attempted the first general sketch of the marine deposits of Italy, their geographical extent and most characteristic organic remains. In his treatise "On the Origin of Springs," he explained their dependence on the order, and often on the dislocations of the strata, and reasoned philosophically against the opinions of those who regarded the disordered state of the earth's crust as exhibiting signs of the wrath of God for the sins of man. He found himself under the necessity of contending in his preliminary chapter against St. Jerome, and four other principal interpreters of scripture, besides several professors of divinity, "that springs did not flow by subterranean syphons and cavities from the sea upwards, losing their saltness in the passage," for this theory had been made to rest on the infallible testimony of Holy Writ.

Although reluctant to generalize on the rich materials accumulated in his travels, Vallisneri had been so much struck with the remarkable continuity of the more recent marine strata, from one end of Italy to the other, that he came to the conclusion that the ocean formerly extended over the whole earth, and abode there for a long time. This opinion, how-

* Ramazzini even asserted, that the ideas of Burnet were mainly borrowed from a dialogue of one Patrizio; but Brocchi, after reading that dialogue, assures us, that there was scarcely any other correspondence between these systems, except that both were equally whimsical.

† Dei Corpi marini, Lettere critiche, &c. 1721.

ever untenable, was a great step beyond Woodward's diluvian hypothesis, against which Vallisneri, and after him all the Tuscan geologists, uniformly contended, while it was warmly supported by the members of the Institute of Bologna*.

Among others of that day, Spada, a priest of Grezzana, in 1737, wrote to prove that the petrified marine bodies near Verona were not diluvian†. Mattani drew similar inference, from the shells of Volterra, and other places; while Costantini, on the other hand, whose observations on the valley of the Brenta and other districts were not without value, undertook to vindicate the truth of the deluge, as also to prove that Italy had been peopled by the descendants of Japhet‡.

Lazzoro Moro, in his work (published in 1740), "On the Marine Bodies which are found in the Mountains§," attempted to apply the theory of earthquakes, as expounded by Strabo, Pliny, and other ancient authors, with whom he was familiar, to the geological phenomena described by Vallisneri||. His attention was awakened to the elevating power of subterranean forces, by a remarkable phenomenon which happened in his own time, and which had also been noticed by Vallisneri in his letters. A new island rose in 1707, from a deep part of the sea near Santorino in the Mediterranean, during continued shocks of an earthquake, and increasing rapidly in size, grew in less than a month to be half a mile in circumference, and about twenty-five feet above high-water mark. It was soon afterwards covered by volcanic ejections, but when first examined it was found to be a white rock, bearing on its surface living oysters and crustacea. In order to ridicule the various theories then in vogue, Moro ingeniously supposes the arrival on this new isle of a party of naturalists ignorant of its recent origin. One immediately points to the marine shells, as proofs of the universal deluge; another argues, that they demonstrate the former residence of the sea upon the mountains; a third dismisses them as mere *sports of nature;*

* Brocchi, p. 28. † Ibid. p. 33. ‡ Ibid. p. 37.

§ Sui Crostacei ed altri Corpi marini che si trovano sui Monti.

|| Moro does not cite the works of Hooke and Ray, and although so many of his views were in accordance with theirs, he was probably ignorant of their writings, for they had not been translated. As he always refers to the Latin edition of Burnet, and a French translation of Woodward, we may presume that he did not read English.

while a fourth affirms, that they were born and nourished within the rock in ancient caverns, into which salt water had been raised in the shape of vapour, by the action of subterranean heat.

Moro pointed with great judgment to the *faults* and dislocations of the strata described by Vallisneri, in the Alps and other chains, in confirmation of his doctrine, that the continents had been heaved up by subterranean movements. He objected, on solid grounds, to the hypotheses of Burnet and of Woodward; yet he ventured so far to disregard the protest of Vallisneri, as to undertake the adaptation of every part of his own system to the Mosaic account of the creation. On the third day, he said the globe was every where covered to the same depth by fresh water, and when it pleased the Supreme Being that the dry land should appear, volcanic explosions broke up the smooth and regular surface of the earth composed of primary rocks. These rose in mountain masses above the waves, and allowed melted metals and salts to ascend through fissures. *The sea gradually acquired its saltness from volcanic exhalations*, and, while it became more circumscribed in area, increased in depth. Sand and ashes ejected by volcanoes were regularly disposed along the bottom of the ocean and formed the secondary strata, which in their turn were lifted up by earthquakes. We shall not attempt to follow him in tracing the progress of the creation of vegetables, and animals on the other days of creation; but, upon the whole, we may remark that few of the old cosmological theories had been conceived with so little violation of known analogies.

The style of Moro was extremely prolix, and, like Hutton, who, at a later period, advanced many of the same views, he stood in need of an illustrator. The Scotch geologist was not more fortunate in the advocacy of Playfair, than was Moro in numbering amongst his admirers Cirillo Generelli, who, nine years afterwards, delivered at a sitting of Academicians at Cremona a spirited exposition of his theory. This learned Carmelitan friar does not pretend to have been an original observer, but he had studied sufficiently to be enabled to confirm the opinions of Moro by arguments from other writers; and his selection of the doctrines then best established is so judicious, that we shall present a brief abstract of them to our readers, as illustrating the state of geology in Europe, and in

Italy in particular, before the middle of the last century. The bowels of the earth, says he, have carefully preserved the memorials of past events, and this truth the marine productions so frequent in the hills attest. From the reflections of Lazzoro Moro we may assure ourselves, that these are the effects of earthquakes in past times, which have changed vast spaces of sea into terra firma, and inhabited lands into seas. In this, more than in any other department of physics, are observations and experiments indispensable, and we must diligently consider facts. The land is known, wherever we make excavations, to be composed of different strata or soils placed one above the other, some of sand, some of rock, some of chalk, others of marl, coal, pumice, gypsum, lime, and the rest. These ingredients are sometimes pure, and sometimes confusedly intermixed. Within are often imprisoned different marine fishes, like dried mummies, and more frequently shells, crustacea, corals, plants, &c., not only in Italy, but in France, Germany, England, Africa, Asia, and America. Sometimes in the lowest, sometimes in the loftiest beds of the earth, some upon the mountains, some in deep mines, others near the sea, and others hundreds of miles distant from it. But there are in some districts rocks, wherein no marine bodies are found. The remains of animals consist chiefly of their more solid parts, and the most rocky strata must have been soft when such exuviæ were inclosed in them. Vegetable productions are found in different states of maturity, indicating that they were imbedded in different seasons. Elephants, elks, and other terrestrial quadrupeds, have been found in England and elsewhere, in superficial strata, never covered by the sea. Alternations are rare, yet not without example, of marine strata, and those which contain marshy and terrestrial productions. Marine animals are arranged in the subterraneous beds with admirable order, in distinct groups, oysters here, dentalia, or corals there, &c., as now, according to Marsilli*, on the shores of the Adriatic. We must abandon the doctrine once so popular, that organized fossils have not been derived from living beings, and we cannot account for their present position by the ancient theory of Strato, nor by that of Leibnitz, nor by the

* Saggio fisico intorno alla Storia del Mare, part i. p. 24.

universal deluge, as explained by Woodward and others, " nor is it reasonable to call the Deity capriciously upon the stage, and to make him work miracles, for the sake of confirming our preconceived hypotheses."—" I hold in utter abomination, most learned Academicians! those systems which are built with their foundations in the air, and cannot be propped up without a miracle; and I undertake, with the assistance of Moro, to explain to you, how these marine animals were transported into the mountains by natural causes*." A brief abstract then follows of Moro's theory, by which, says Generelli, we may explain all the phenomena, as Vallisneri so ardently desired, " *without violence, without fictions, without hypotheses, without miracles*†." The Carmelitan then proceeds to struggle against an obvious objection to Moro's system, considered as a method of explaining the revolutions of the earth, *naturally*. If earthquakes have been the agents of such mighty changes, how does it happen that their effects since the times of history have been so inconsiderable? This same difficulty had, as we have seen, presented itself to Hooke, half a century before, and forced him to resort to a former " crisis of nature;" but Generelli defended his position by shewing how numerous were the accounts of eruptions and earthquakes, of new islands, and of elevations and subsidences of land, and yet how much greater a number of like events must have been unattested and unrecorded during the last six thousand years. He also appealed to Vallisneri as an authority to prove that the mineral masses containing shells bore, upon the whole, but a small proportion to those rocks which were destitute of organic remains; and the latter, says the learned monk, might have been created as they now exist, *in the beginning*. He then describes the continual waste of mountains and continents, by the action of rivers and torrents, and concludes with these eloquent and original observations: " Is it possible that this waste should have continued for six thousand, and *perhaps* a greater number of years, and that the mountains should remain so great, unless their ruins have been repaired? Is it credible that the Author of

* Abbomino al sommo qualsivoglia sistema, che sia di pianta fabbricato in aria; massime quando è tale, che non possa sostenersi senza un miracolo, &c. De' Crostacei e di altre produz. del Mare, &c. 1749.

† Senza violenze, senza finzioni, senza supposti, senza miracoli,—*Ib.*

nature should have founded the world upon such laws, as that the dry land should for ever be growing smaller, and at last become wholly submerged beneath the waters? Is it credible that, amid so many created things, the mountains alone should daily diminish in number and bulk, without there being any repair of their losses? This would be contrary to that order of Providence which is seen to reign in all other things in the universe. Wherefore I deem it just to conclude, that the same cause which, in the beginning of time, raised mountains from the abyss, has, down to the present day, continued to produce others, in order to restore from time to time the losses of all such as sink down in different places, or are rent asunder, or in other ways suffer disintegration. If this be admitted, we can easily understand why there should now be found upon many mountains so great a number of crustacea and other marine animals."

The reader will remark, that although this admirable essay embraces so large a portion of the principal objects of geological research, it makes no allusion to the extinction of certain classes of animals; and it is evident that no opinions on this head had, at that time, gained a firm footing in Italy. That Lister and other English naturalists should long before have declared in favour of the loss of species, while Scilla and most of his countrymen hesitated, was natural, since the Italian museums were filled with fossil shells, belonging to species of which a great portion did actually exist in the Mediterranean, whereas the English collectors could obtain no recent species from their own strata.

The weakest point in Moro's system consisted in deriving *all* the stratified rocks from volcanic ejections, an absurdity which his opponents took care to expose, especially Vito Amici*. Moro seems to have been misled by his anxious desire to represent the formation of secondary rocks as having occupied an extremely short period, while at the same time he wished to employ known agents in nature. To imagine torrents, rivers, currents, partial floods, and all the operations of moving water, to have gone on exerting an energy many thousand times greater than at present, would have appeared preposterous and incredible, and would have

* Sui Testacei della Sicilia.

required a hundred violent hypotheses; but we are so unacquainted with the true sources of subterranean disturbances, that their former violence may in theory be multiplied indefinitely, without its being possible to prove the same manifest contradiction or absurdity in the conjecture. For this reason, perhaps, Moro preferred to derive the materials of the strata from volcanic ejections, rather than from transportation by running water.

Marsilli, in the work above alluded to by Generelli, had been prompted to institute inquiries into the bed of the Adriatic, by discovering in the territory of Parma, (what Spada had observed near Verona, and Schiavo in Sicily,) that fossil shells were not scattered through the rocks at random, but disposed in regular order, according to families. But with a view of throwing further light upon these questions, Donati, in 1750, undertook a more extensive investigation of the Adriatic, and discovered, by numerous soundings, that deposits of sand, marl, and tufaceous incrustations, most strictly analogous to those of the Subapennine hills, were in the act of accumulating there. He ascertained that there were no shells in some of the submarine tracts, while in other places they lived together in families, particularly the genera Arca, Pecten, Venus, Murex, and some others. A contemporary naturalist, Baldassari, had shewn the same grouping of organic remains in the tertiary marls of the Sienese territory.

Buffon first made known his theoretical views concerning the former changes of the earth in his Natural History, published in 1749. His opinions were directly opposed to the systems of Hooke, Ray, and Moro, for he attributed no influence whatever to subterranean movements and volcanoes, but returned to the universal ocean of Leibnitz. By this aqueous envelope the highest mountains were once covered. Marine currents then acted violently, and formed horizontal strata, by washing away land in some parts, and depositing it in others; they also excavated deep submarine valleys. He was greatly at a loss for some machinery to depress the level of the ocean, and cause the land to be left dry. He therefore speculated on the possibility of subterranean caverns having opened, into which the water entered, so that he involuntarily approximated to Hooke's theory of subsidences by earthquakes.

Buffon had never profited, like Moro, by the observations of Vallisneri, or he never could have imagined that the strata were generally horizontal, and that those which contain organic remains had never been disturbed since the era of their formation. He was conscious of the great power annually exerted by rivers and marine currents in transporting earthy materials to lower levels, and he even contemplated the period when they would destroy all the present continents. Although in geology he was not an original observer, his genius enabled him to render his hypothesis attractive; and by the eloquence of his style, and the boldness of his speculations, he awakened curiosity and provoked a spirit of inquiry amongst his countrymen.

Soon after the publication of his "Natural History," in which was included his "Theory of the Earth," he received an official letter (dated January, 1751), from the Sorbonne or Faculty of Theology in Paris, informing him that fourteen propositions in his works "were reprehensible and contrary to the creed of the church." The first of these obnoxious passages, and the only one relating to geology, was as follows. "The waters of the sea have produced the mountains and valleys of the land—the waters of the heavens, reducing all to a level, will at last deliver the whole land over to the sea, and the sea, successively prevailing over the land, will leave dry new continents like those which we inhabit." Buffon was invited by the College in very courteous terms, to send in an explanation, or rather a recantation, of his unorthodox opinions. To this he submitted, and a general assembly of the Faculty having approved of his "Declaration," he was required to publish it in his next work. The document begins with these words—"I declare that I had no intention to contradict the text of Scripture; that I believe most firmly all therein related about the creation, both as to order of time and matter of fact; and *I abandon everything in my book respecting the formation of the earth*, and generally all which may be contrary to the narration of Moses*."

The grand principle which Buffon was called upon to renounce was simply this, "that the present mountains and valleys of the earth are due to secondary causes, and that the same causes will in time destroy all the continents, hills

* Hist. Nat. tom. v. Ed. de l'Imp. Royale, Paris, 1769.

and valleys, and reproduce others like them." Now, whatever may be the defects of many of his views, it is no longer controverted, that the present continents are of secondary origin. The doctrine is as firmly established as the earth's rotation on its axis; and that the land now elevated above the level of the sea will not endure for ever, is an opinion which gains ground daily, in proportion as we enlarge our experience of the changes now in progress.

Hollmann was the author of a Memoir in the Transactions of the Royal Society of Gottingen in 1753, wherein he proposed an hypothesis closely corresponding to the opinions of Buffon; and devoted the rest of his work to refuting certain diluvial theories of his day.

Targioni, in his voluminous "Travels in Tuscany, 1751 and 1754," laboured to fill up the sketch of the geology of that region, left by Steno sixty years before. Notwithstanding a want of arrangement and condensation in his memoirs, they contained a rich store of faithful observations. He has not indulged in many general views, but in regard to the origin of valleys he was opposed to the theory of Buffon, who attributed them principally to submarine currents. The Tuscan naturalist laboured to shew that both the larger and smaller valleys of the Apennines were excavated by rivers, and floods, caused by the bursting of the barriers of lakes, after the retreat of the ocean. He also maintained that the elephants, and other quadrupeds so frequent in the lacustrine and alluvial deposits of Italy, had inhabited that peninsula; and had not been transported thither, as some had conceived, by Hannibal, or the Romans, nor by what they were pleased to term "a catastrophe of nature."

Arduino *, in his memoirs on the mountains of Padua, Vicenza, and Verona, first recognized the distinction between primary, secondary, and tertiary rocks, and shewed that in those districts there had been a succession of submarine volcanic eruptions. In the very same year the treatise of Lehman †, a German mineralogist, and director of the Prussian mines, appeared, who also divided mountains into three classes: the

* Giornale del Griselini, 1759.

† Essai d'une Hist. Nat. de Couches de la Terre, 1759.

first, which were formed with the world and prior to the creation of animals, and which contained no fragments of other rocks; the second class, of mountains which resulted from the partial destruction of the primary rocks by a general revolution; and the third class, which resulted from local revolutions, and, in part, from the Noachian deluge.

In the following year (1760) the Rev. John Michell, Woodwardian Professor of Mineralogy at Cambridge, published in the Philosophical Transactions, an Essay on the Cause and Phenomena of Earthquakes. His attention had been drawn to this subject by the great earthquake of Lisbon in 1755. He advanced many original and philosophical views respecting the propagation of subterranean movements, and the caverns and fissures wherein steam might be generated. In order to point out the application of his theory to the structure of the globe, he was led to describe the arrangement and disturbance of the strata, their usual horizontality in low countries, and their contortions and fractured state in the neighbourhood of mountain chains. He also explained, with surprising accuracy, the relations of the central ridges of older rocks to the "long narrow slips of similar earths, stones, and minerals," which are parallel to these ridges. In his generalizations, derived in great part from his own observations on the geological structure of Yorkshire, he anticipated many of the views more fully developed by later naturalists *.

Michell's papers were entirely free from all physico-theological disquisitions, but some of his contemporaries were still earnestly engaged in defending or impugning the Woodwardian hypothesis. We find many of these writings referred to by Catcott, an Hutchinsonian, who published a "Treatise on the Deluge" in 1761. He laboured particularly to refute an explanation offered by his contemporary, Bishop Clayton, of the Mosaic writings. That prelate had declared that the Deluge "could not be literally true, save in respect to that part where Noah lived before the flood." Catcott insisted on the univer-

* Some of Michell's observations anticipate in so remarkable a manner the theories established forty years afterwards, that his writings would probably have formed an era in the science, if his researches had been uninterrupted. He held, however, his professorship only eight years, when he succeeded to a benefice, and from that time he appears to have entirely discontinued his scientific pursuits.

sality of the deluge, and referred to traditions of inundations mentioned by ancient writers, or by travellers in the East-Indies, China, South America, and other countries. This part of his book is valuable, although it is not easy to see what bearing the traditions have, if admitted to be authentic, on the Bishop's argument, since no evidence is adduced to prove that the catastrophes were contemporaneous events, while some of them are expressly represented by ancient authors to have occurred in succession.

The doctrines of Arduino, above adverted to, were afterwards confirmed by Fortis and Desmarest, in their travels in the same country, and they, as well as Baldassari, laboured to complete the history of the Subapennine strata. In the work of Odoardi *, there was also a clear argument in favour of the distinct ages of the older Apennine strata, and the Subapennine formations of more recent origin. He pointed out that the strata of these two groups were *unconformable*, and must have been the deposits of different seas at distant periods of time.

A history of the new islands by Raspe, an Hanoverian, appeared in 1763, in Latin. In this work, all the authentic accounts of earthquakes which had produced permanent changes on the solid parts of the earth were collected together and examined with judicious criticism. The best systems which had been proposed concerning the ancient history of the globe, both by ancient and modern writers, are reviewed. The merits and defects of the systems of Hooke, Ray, Moro, Buffon, and others, are fairly estimated. Great admiration is expressed for the hypothesis of Hooke, and his explanation of the origin of the strata is shewn to have been more correct than Moro's, while their theory of the effects of earthquakes was the same. Raspe had not seen Michell's memoir, and his views concerning the geological structure of the earth were perhaps less enlarged, yet he was able to add many additional arguments in favour of Hooke's theory, and to render it, as he said, a nearer approach to what Hooke would have written had he lived in later times. As to the periods wherein all the earthquakes happened, to which we owe the elevation of various parts of our continents and islands, Raspe says he pretends not to assign their duration,

* Sui Corpi Marini del Feltrino, 1761.

still less to defend Hooke's suggestion, that the convulsions almost all took place during the Noachian deluge. He adverts to the apparent indications of the former tropical heat of the climate of Europe, and the changes in the species of animals and plants, as among the most obscure and difficult problems in geology. In regard to the islands raised from the sea, within the times of history or tradition, he declares that some of them were composed of strata containing organic remains, and that they were not, as Buffon had asserted, made of mere volcanic matter. His work concludes with an eloquent exhortation to naturalists, to examine the isles which rose in 1707, in the Grecian Archipelago, and in 1720 in the Azores, and not to neglect such splendid opportunities of studying nature "in the act of parturition." That Hooke's writings should have been neglected for more than half a century, was matter of astonishment to Raspe; but, it is still more wonderful that his own luminous exposition of that theory should, for more than another half century, have excited so little interest.

Gustavus Brander published, in 1766, his "Fossilia Hantoniensia," containing excellent figures of fossil shells from the more modern marine strata of our island. "Various opinions," he says in the preface, "had been entertained concerning the time when and how these bodies became deposited. Some there are who conceive that it might have been effected in a wonderful length of time by a gradual changing and shifting of the sea, &c. But the most common cause assigned is that of "the deluge." This conjecture, he says, even if the universality of the flood be not called in question, is purely hypothetical. In his opinion fossil animals and testacea were, for the most part, of unknown species, and of such as were known, the living analogues now belonged to southern latitudes.

Soldani* applied successfully his knowledge of zoology to illustrate the history of stratified masses. He explained that microscopic testacea and zoophytes inhabited the depths of the Mediterranean, and that the fossil species were, in like manner, found in those deposits wherein the fineness of their particles, and the absence of pebbles, implied that they were accumulated in a deep sea far from any shore. This author first remarked the alternation of marine and fresh-water strata in the Paris

* Saggio orittografico, &c. 1780, and other Works.

basin. A lively controversy arose between Fortis and another Italian naturalist, Testa, concerning the fish of Monte Bolca, in 1793. Their letters*, written with great spirit and elegance, shew that they were aware that a large proportion of the Subapennine shells were identical with living species, and some of them with species now living in the torrid zone. Fortis conjectured that when the volcanos of the Vicentin were burning, the waters of the Adriatic had a higher temperature; and in this manner, he said that the shells of warmer regions may once have peopled their own seas. But Testa was disposed to think, that these species of testacea were still common to their own and to equinoctial seas, for many, he said, once supposed to be confined to hotter regions, had been afterwards discovered in the Mediterranean †.

While these Italian naturalists, together with Cortesi and Spallanzani, were busily engaged in pointing out the analogy between the deposits of modern and ancient seas, and the habits and arrangement of their organic inhabitants, and while some progress was making in the same country, in investigating the ancient and modern volcanic rocks, the most original observers among the English and German writers, Wallerius and Whitehurst ‡, were wasting their strength in contending, according to the old Woodwardian hypothesis, that all the strata were formed by the Noachian deluge. But Whitehurst's description of the rocks of Derbyshire was most faithful, and he atoned for false theoretical views, by providing data for their refutation.

The mathematician, Boscovich, of Ragusa in Dalmatia, in his letters, published at Venice in 1772, declared his persuasion, that the effects of earthquakes, although insensible in the course of a few years, do nevertheless raise, from time to time,

* Lett. sui Pesci Fossili di Bolca. *Milan*, 1793.

† This argument of Testa has been strengthened of late years by the discovery, that dealers in shells had long been in the habit of selling Mediterranean species as shells of more southern and distant latitudes, for the sake of enhancing their price. It appears, moreover, from several hundred experiments made by that distinguished hydrographer Captain Smyth, on the water within eight fathoms of the surface, that the temperature of the Mediterranean is on an average $3\frac{1}{2}°$ of Fahrenheit higher than the western part of the Atlantic ocean; an important fact which in some degree may help to explain why many species are common to tropical latitudes, and to the Mediterranean.

‡ Inquiry into the Original State and Formation of the Earth. 1778.

and let down different parts of the crust of our globe, and sometimes fold and twist them. Like Hooke, Ray, and Moro, he conceived the subterranean movements to have acted with greater energy at former epochs.

Towards the close of the eighteenth century, the idea of distinguishing the mineral masses on our globe into separate groups, and studying their relations, began to be generally diffused. Pallas and Saussure were among the most celebrated whose labours contributed to this end. After an attentive examination of the two great mountain chains of Siberia, Pallas announced the result that the granitic rocks were in the middle, the schistose at their sides, and the limestones again on the outside of these; and this he conceived would prove a general law in the formation of all chains composed chiefly of primary rocks *.

In his "Travels in Russia," in 1793 and 1794, he made many geological observations on the recent strata near the Wolga and the Caspian, and adduced proofs of the greater extent of the latter sea at no distant era in the earth's history. His memoir on the fossil bones of Siberia attracted attention to some of the most remarkable phenomena in geology. He stated that he had found a rhinoceros entire in the frozen soil, with its skin and flesh: an elephant, found afterwards in a mass of ice on the shore of the north sea, removed all doubt as to the accuracy of so wonderful a discovery †.

The subjects relating to natural history which engaged the attention of Pallas were too multifarious to admit of his devoting a large share of his labours exclusively to geology. Saussure, on the other hand, employed the chief portion of his time in studying the structure of the Alps and Jura, and he provided valuable data for those who followed him. We cannot enter into the details of these observations, and he did not pretend to have arrived at any general system. The few theoretical observations which escaped from him are, like those of Pallas, mere modifications of the old cosmological doctrines.

* Observ. on the Formation of Mountains, Act. Petrop. ann. 1778, part i.

† Nov. comm. Petr. XVII. Cuvier, Eloge de Pallas.