

Scientific Premises of Geology in the Encyclopédie of Diderot and d'Alembert

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ABSTRACT

The *Encyclopédie* (1751-1772), conceived and directed by Diderot and d'Alembert, was intended to be a critical compendium of all the learning of the time and to provide society with a rational knowledge free from dogma and superstition. It was produced with private capital and involved a large team of distinguished scientists and philosophers. It consists of 17 volumes of text and 11 of plates. At the time geology was in its infancy and the *Encyclopédie* collects together works by Agricola, Steno, Lehman and Wallerius. The French geologist Nicolas Desmarest (1725-1815) studied the volcanic area of Auvergne in the Central Massif of France, his ideas on volcanism and the internal structure of the Earth can be found in the *Encyclopédie*, which would later be published separately. Although it does not contribute much that is new to the Earth sciences, it is important in helping us to assess the environment in which the Encyclopaedists moved and better appreciate what their critical spirit and fight against dogmatism represented in the creation of modern thought.

Key words: encyclopedia, history of geology, physical geography, volcano, flood

La geología en la enciclopedia de Diderot y d'Alembert

RESUMEN

La Encyclopédie (1751-1772), que lleva por subtítulo "Diccionario razonado de las ciencias, las artes y los oficios", pretende ser el compendio crítico de todos los saberes de su tiempo liberándolo de dogmas y supersticiones. En el artículo dedicado a la palabra "Enciclopedia", Diderot dice textualmente: "La finalidad de una Enciclopedia es reunir todos los conocimientos dispersos en la superficie de la Tierra y exponer su sistema general a los hombres entre los cuales vivimos y transmitirlos a los que nos sucederán". Esto es lo que trata de lograr con la obra, aunque es consciente de que cada día se realizan nuevos descubrimientos que hacen progresar las ciencias y este conocimiento será sobrepasado por las nuevas generaciones. Jorge Luís Borges (Ricci 1978) sostiene que su publicación es uno de los acontecimientos más importantes de la historia europea, cuyo objetivo principal fue la conquista de la libertad intelectual y moral y, como dice Diderot en el mismo artículo, "comenzar a sacudir el yugo de la autoridad y el ejemplo para apoyarse en las leyes de la razón"; "no buscar las reglas en los autores sino en la naturaleza". Sólo el "libre ensayo" de la razón humana permite el conocimiento de la naturaleza, y es la razón quien debe abordar su estudio sin aceptar ningún límite ni tutela por parte de la religión o la tradición.

Palabras clave: enciclopedia, geografía física, historia de la geología, inundación ,volcán

VERSIÓN ABREVIADA EN CASTELLANO

En el artículo dedicado a la palabra "Enciclopedia", Diderot dice textualmente: "La finalidad de una Enciclopedia es reunir todos los conocimientos dispersos en la superficie de la Tierra y exponer su sistema general a los hombres entre los cuales vivimos y transmitirlo a los hombres que nos sucederán" y esto es lo que trata de lograr, aunque consciente de que este conocimiento será sobrepasado por las nuevas generaciones. Su objetivo principal fue la conquista de la libertad intelectual y moral y "sacudir el yugo de la

autoridad y el ejemplo para apoyarse en las leyes de la razón"; "no buscar las reglas en los autores sino en la naturaleza", sin aceptar ningún límite ni tutela por parte de la religión o de la tradición.

Concebida y dirigida por Diderot y d'Alembert, es obra de un equipo de personas no pertenecientes a la Academia de Ciencias y libres de la tutela de la Iglesia y del monarca a través de una empresa comercial con capitales privados, donde el poder real sólo intervino para obstaculizar su difusión. Consta de 28 volúmenes, 17 de texto y 11 de láminas, el primero de los cuales se publica en 1751 y los últimos en 1772, fecha en la que termina la Encyclopédie. Entre 1776 y 1784 aparecen unos suplementos de texto y láminas sin Diderot ni la mayor parte de sus colaboradores. Tuvo amplia difusión y se realizaron probablemente siete ediciones más entre 1770 y 1780, pero sólo están bien documentadas hasta la cuarta. Tiene especial interés la tercera (1777-1779), con Ginebra como lugar de edición, aunque no está claro dónde se imprimió (Blom 2004), ya que parece que recupera, al menos en parte, los materiales que Diderot había enviado a la imprenta pero el editor había retirado por miedo a que, como anteriormente, las autoridades prohibieran su distribución una vez impresos. Esta tercera edición, de 36 volúmenes, ya que incluye los textos que en las dos primeras ediciones aparecieron en los suplementos, es la que se encuentra en la mayoría de las bibliotecas y también la que ha sido digitalizada por la Biblioteca Nacional de Francia (www.bnf.fr). También puede consultarse on-line (<http://quod.lib.umich.edu/d/did>) una traducción inglesa, "The Encyclopedia of Diderot & d'Alembert, collaborative translation Project" de la Universidad de Michigan, pero es muy incompleta, ya que le faltan bastantes artículos.

Cuando se emprende la redacción de la Encyclopédie, aparte de la física, las matemáticas y la astronomía, las ciencias están en sus comienzos. Sólo han sido estudiados los yacimientos minerales (Agrícola), la sistemática de los vegetales y, menos, de los animales, la descripción de las características de los seres vivos, y la composición y origen del sistema solar y nuestro planeta (Buffon). La geología empieza de manera difusa dentro de la filosofía, ya que la estructura y el origen del planeta preocuparon desde siempre a los pensadores y la humanidad se preocupó desde sus orígenes por la búsqueda y extracción de los minerales. Georges Bauer, Agrícola (1494-1555), publicó su *De re metalica* (Agrícola, 1556), tratado de minería y metalurgia de amplia difusión y recogido en la Encyclopédie. Hay que esperar un siglo hasta que se publiquen los primeros trabajos explícitamente geológicos, obra de Nicolás Steno, que no sólo identifica y describe los restos de fósiles marinos sino que también establece el concepto de estrato y de procesos de sedimentación e introduce el concepto del tiempo en los procesos geológicos al indicar que los estratos más profundos son más antiguos. Contemporáneos, pero muy diferentes, son los trabajos de los filósofos-teólogos que intentan explicar la evolución de la Tierra de acuerdo con la narración bíblica (Thomas Burnet (1635-1715), John Woodward (1665-1728) y William Whiston (1667-1752)). Georges-Louis Leclerc, conde de Buffon (1707-1788), heredero de la tradición anterior, la sintetiza en los 44 tomos de su monumental *Histoire Naturelle*. El primer volumen (1749) contiene un trabajo geológico, "Historia y teoría de la Tierra", con un modelo del origen de nuestro planeta, desde una nebulosa que da origen a todo el sistema solar hasta la estructura actual, ideas que recoge la Encyclopédie, aunque parece que no colaboró a pesar de que así se había anunciado. Algo posterior es el geólogo francés Nicolas Desmarest (1725-1815), que estudió la región volcánica francesa de Auvernia y consideró a los basaltos resultado de la solidificación de las lavas emitidas por volcanes ya extinguidos. Aunque sus obras no aparecieron hasta unos años después, sus ideas sobre el vulcanismo y la estructura interna de la Tierra se encuentran recogidas en la Encyclopédie.

En esta nota se analizan los términos relacionados con las ciencias de la Tierra exceptuando los de mineralogía y metalurgia. Lo primero que llama la atención es que no figura la palabra geología y el contenido de la misma se describe como geografía física, aunque el término "Geología" sí se cita en el cuadro de clasificación de "los conocimientos humanos" considerándola la "ciencia de los continentes".

"Geografía Física" es un artículo de gran extensión (26 páginas). Desmarest, su redactor, la define como la "descripción razonada de los grandes fenómenos de la Tierra y la consideración de los resultados generales deducidos de las observaciones locales y particulares" y, aparte de que incluye la meteorología, hidrología, climatología y oceanografía, su contenido es el mismo que hasta hace poco se aceptaba. Dedicó buena parte del artículo a exponer la metodología, insistiendo en que este estudio debe basarse en "la observación de los hechos", a fin de poder "clasificar los fenómenos" y deducir "unos principios generales".

El artículo sobre "Volcanes" debido a Holbach (Paul Henri Thiry, Barón de Holbach, 1723-1789) es uno de los mejores de la Encyclopédie en lo que se refiere a geología. Supone la Tierra "rellena de substancias capaces de alimentar el fuego", causantes de los volcanes y de los terremotos. Es interesante la referencia a los volcanes de Auvernia y el reconocimiento de que las coladas de lava de esta región son el resultado de antiguas erupciones, realmente novedoso en aquella época, como la referencia al vulcanismo submarino, y el conocimiento del planeta que demuestra la gran cantidad de volcanes que cita en las más diversas regiones.

El interés del artículo sobre los "Terremotos" está en la visión del autor de la constitución del interior de la Tierra, al considerar a estos movimientos responsables de los cambios producidos en el Globo, que

denomina "revoluciones", la mayoría de las cuales considera muy antiguas y sugiere algunos de los posibles cambios que podrían haberse producido, por ejemplo que Gran Bretaña hubiera estado unida al continente europeo o Sicilia a la Península Italiana, observación interesante ya que entonces se aceptaba que la Tierra había tenido siempre el mismo aspecto desde su creación, exceptuando los cambios producidos por el Diluvio Universal.

El artículo sobre el "Diluvio" de Diderot es un texto ortodoxo respecto a las enseñanzas de la Iglesia, muy diferente de los que se refieren a las ciencias de la Tierra. También llama la atención que esté construido a base de un artículo que Nicolás Boulanger no llegó a publicar, que reproduce entrecortado y representa casi un 90 % del total, razón por la cual este artículo aparece a veces atribuido a este autor. Sin duda Diderot lo redactó pensando que sería revisado por los censores, en busca de herejía que diera motivos para prohibir otra vez la Encyclopédie. No hay que olvidar que, por entonces, negar la existencia del Diluvio Universal como lo describe la Biblia era enfrentarse con las autoridades religiosas.

En la Encyclopédie intuyen lo que más tarde explicarán Hutton, Werner y Lyell, y rompen con la tradición vigente de los geólogos-teólogos Burnet, Whiston y Woodward, que intentaban explicar la historia de la Tierra recurriendo a la Biblia. Sostienen que la Tierra ha cambiado y sigue cambiando por acción de su energía interna, y sugieren una edad muy superior a la que se proponía. Sin negar la existencia del Diluvio Universal, minimizan su acción en el origen de los fósiles y el modelado terrestre. En resumen, si bien esta obra no supone una gran aportación en el campo de las ciencias de la Tierra, sí representa un nuevo enfoque, antes de que en el siglo XVIII y XIX su método científico se consolide. Es además muy importante para valorar el ambiente en que se movieron los enciclopedistas y así apreciar mejor lo que su espíritu crítico y lucha contra los dogmatismos representó en la creación del pensamiento moderno.

Introduction

The *Encyclopédie*, subtitled "a systematic dictionary of the sciences, arts and crafts", endeavours to give a lucid and rational understanding of the world, liberating humanity from superstitions, and to this end aims to be a critical compendium of all the accumulated knowledge of the time. In the article dedicated to the word "*Encyclopaedia*", Diderot states: "*The purpose of an Encyclopaedia is to collect knowledge disseminated around the globe; to set forth its general system to the men with whom we live, and transmit it to those who will come after us*". This is what he is trying to achieve with the work, although he is aware that every day there are new discoveries and advances in the sciences, and so this knowledge will be transcended by future generations. Jorge Luis Borges (Ricci 1978) affirms that its publication is one of the most important events in European history, whose main objective is the conquest of intellectual and moral freedom, and, as Diderot states in the same article, "*begin to shake off the yoke of authority and example to hold to the laws of reason*"; "*no longer look for the rules in authors, but in nature*". Only the free use of human reason allows a true understanding of nature; and reason should address its study without accepting any limits or tutelage by religion or tradition. With this same purpose, Antoine Furètière (1619-1688) produced a dictionary which was not published until 1694, a few years after his death and was vehemently refuted by both the Church and public institutions. Subsequently the Jesuits, under

the protection of Louis Auguste de Bourbon, son of Louis XIV, published the Trévoux Dictionary (1704), which took its name from the place of publication.

The project, conceived and directed by Diderot and d'Alembert, is the work of a team of people, as indicated in the title, "*une société de gent de lettres*", who does not belong to the Academy of Sciences and are free from the tutelage of the Church and the monarchy. It was carried out through a commercial company with private capital, and royal powers only intervened to hamper its distribution. It consists of 28 volumes, 17 of text and 11 of plates, the first of which was published in 1751 and the last in 1772, the date of the end of the adventure of the *Encyclopédie*. Some text and plate supplements appear between 1776 and 1784, but neither Diderot nor many of his collaborators intervened. It was widely distributed and seven editions were probably produced between 1770 and 1780, but they are only well documented up to the fourth. The third (1777-1779) has special interest, in which Geneva is indicated as the place where it was edited, although it is not clear where it was printed (Blom 2004), since it seems that some material was recovered that Diderot had sent to the press but that the editor had removed for fear that the authorities would ban its distribution once it was printed. In any case, this suppression does not seem to have affected the subject of Earth sciences, although this is not true in the case of references to the biblical Flood, which at this time was a controversial subject. The weight of this self-censure can be observed as the majority of articles which are absolutely critical of the teachings

of the Bible, co-exist with those dedicated to this entry, which is completely orthodox. This third edition, which contains 36 volumes, as it includes texts which in the first two editions appeared in the supplements, is the one which can be found in the majority of libraries and is also the one which has been digitalized by the Bibliothèque Nationale de France (www.bnf.fr), and for which reason has been used as the basis for the analysis on which this article is founded. It is also possible to consult on line (<http://quod.lib.umich.edu/d/did>) an English translation, "The Encyclopédie of Diderot & d'Alembert, collaborative translation Project" of The University of Michigan, but it is quite incomplete as many articles are not included.

When the writing of the *Encyclopédie* commenced, apart from physics, mathematics and astronomy, the sciences were in their infancy. The only area of natural sciences to be studied in detail were mineral deposits (Agricola, Walerius and Lehman), the systematic of plants and animals (Linné, Ray, Réaumur and or Tournefort ?), the description of the characteristics of living organisms and the composition and origin of the Solar System and our planet (Buffon). Voltaire wrote a work on Newton in order to make him known in France, Diderot was an enthusiast of Buffon, just as Rousseau was of Linneo and Desmarest collaborated in the *Encyclopédie*. For this reason the thoughts of these four authors are collected within, as well as the works of Agricola on mining and metallurgy, which were completed with the study of some mines, carried out by contemporaneous engineers and friends of Diderot, especially Holbach.

The *Encyclopédie* shows little interest in science, the article dedicated to "Eléments de Science" is devoted to philosophical reflexions; it dedicates a single line to physics which is considered to correspond to the observation of the Universe, and to natural history which it considers to be an object of philosophical meditation.

The *Encyclopédie* has been the subject of numerous studies, but life and Earth sciences have received little attention. Roger (*in Ricci* 1978) studies the life sciences in more details, and refers to the Earth sciences in a brief, but accurate analysis. It was therefore considered appropriate to carry out this study with greater emphasis on the text of the third edition of the *Encyclopédie*.

Geology in the times of the Encyclopedia

In geology the situation is different from physics in which Newton carried out his experiments. The "laboratory" of geology is the field: the mountain

ranges and the oceans, the plains and river channels, the glaciers and deserts... To carry out observations is more complex, experimentation is still more difficult. First we have a question of scale, not only spatial which necessitates long journeys and impedes observation in many areas which are practically inaccessible, for instance the ocean depths or the Earth's interior, but also the fundamental problem is in the temporal dimension of geological phenomena, which happen over a timescale completely different from that of humans. Chronicles and stories help to keep memory of the history of mankind, the succession of generations, but it is not easy for our minds to imagine a world before us, without the presence of some individuals to observe and subsequently transmit these observations. Myths and religion serve this function.

The subject of geology began in a quite diffuse manner within philosophy as the structure and origin of the planet we live on, has always engaged the attention of the great thinkers. Copernicus (1473-1543) outlined a theory on the origin and composition of the Earth, which some years later was elaborated on by Descartes in the fourth chapter of *Les Principes de la Philosophie* (1647-1723). Later he wrote a treatise, *Le Monde*, which gave more information about the composition and history of the Earth and life, but after the sentence passed on Galileo in 1663, he destroyed it for fear of reprisals from the ecclesiastical authorities. *Les Principes* is divided into four parts and it is in the fourth (*De la Terre*) where he sets out his ideas on the structure and composition of the Earth, although most of the text is devoted to physics, meteorology and hydrology. The ideas expressed in *Les Principes* are both novel and heterodox, he maintains that the Earth does not have the same aspect as when it was formed, but was generated as a result of a nebula whose particles condensed to form the Sun and all the planets. It is interesting to stress that Descartes maintains that his ideas are nothing new and refers to Aristotle and other philosophers: "*je ne m'y suis néanmoins servi d'aucun principe qui n'ait été recrû & approuvé par Aristote, & tous les autres Philosophes qui ont jamais été au monde, en sorte que cette Philosophie n'est point nouvelle*".

Aside from these theoretical reflections, humanity has given special attention to the search and extraction of minerals. Georges Bauer Agricola, (1494-1555) was a physician and was interested in the medicinal properties of minerals as well as having; he had contact with the mining exploitations in Saxony for family reasons. In 1556, he published *De re metalica*, a treatise on mining and metallurgy;

he also wrote *De ortu et causis subterraneorum*, in which he explains the terrestrial relief in terms of erosion by water, and *De natura fossilium*, in which he interprets fossils as the remains of ancient living creatures. These works were widely distributed and influenced subsequent authors for many years, having been collected together in the *Encyclopédie*.

In any case we have to wait some time until the first works which are explicitly geological are published, the work of Nicolas Steno (Niels Stensen), (1638-1686), a Danish physician who had just moved to Florence where he became interested in the fossil remains which are contained in the materials which form the subsoil of Tuscany. In 1669 he published the *Canis carchiae*, in which not only does he identify and describe the remains of marine fossils but also establishes the concept of strata and the processes of sedimentation. He recognizes the marine origin of materials which are currently in emerged areas, without recurring to the biblical Flood, although he evidently accepts its occurrence, and introduces the concept of time into geological processes when he indicates that the deeper strata are older than those which cover them. His idea that by observing the composition of the subsoil of a region it is possible to recognize the changes which have occurred in the past is an important one. He believes they are caused by "the internal fire" of the Earth, which not only manifests itself in volcanoes but also in the deformations of the strata which can be observed in mountains. As such, in his work *Solidum intra solidum naturaliter* (1669) he states that "all the mountains that exist today have not existed since the origin of everything in this world". Some authors suggest that the work of Steno fell into obscurity, but part was recovered by Leibniz in *Protozea* (1690-1691), in which he expounds the idea that the Earth was originally an incandescent mass which subsequently cooled slowly, an idea repeated by Buffon in *Les époques de la nature*.

The "philosopher-theologians" are contemporary to Steno but very different in style, they attempt to explain the origin and evolution of the Earth in accordance with the biblical narrative. The most important of these was Thomas Burnet (1635-1715), who in his work *Telluris teoria sacra* (1680) insists upon the enormous importance of the deluges caused by the biblical Flood on the modelling of mountains and rock formations. John Woodward (1665-1728) in his work *Natural History of the Earth* (1723, 3^a ed.) makes the same assumption but insists still more upon the action of the Flood to explain the modern shape and formation of sediments, and even describes the Earth in the times of the Garden of

Eden. William Whiston (1667-1752) in *A New Theory of the Earth* (1696) explains the Flood in terms of planetary movements that liberated the waters from the interior of the Earth.

Wallerius (1709 – 1785), professor of the University of Uppsala, dedicated himself not only to the study of chemistry and agriculture, but also mineralogy. He described several new minerals, including realgar and cerussite, and also studied various lead mines. Holbach, who wrote the articles on mineralogy in the *Encyclopédie*, knew his work as he had translated it into French.

Buffon inherited this previous tradition and synthesized it in his 44 volumes of the monumental *Histoire naturelle*. The first volume (1749) contains a work of a geological nature, "History and theory of the Earth" in which he elaborates a model of the origin of our planet, from a nebula which was the origin of the entire solar system up to the current structure. He adopts the ideas of Steno with regard to sedimentation and the formation of strata as well as the origin of fossils and considers that the terrestrial relief is due to water erosion. He supposes that when the Earth's crust first formed it was one single continent which later became fragmented. Buffon did not base his idea only on the similarity of the coastlines of South America and Africa but also on the resemblance of the fauna, so in some ways he intuited the theory of continental drift. He also intuited the evolution of living organisms when he indicates that the natural environment can influence their characteristics (Alsina Calvés 2009). In a later work, *Les époques de la nature* (1778), he highlights the time factor in the cooling of the Earth and calculates an age of 74832 years, with which he proposes to interpret the days of Creation as seven stages of long duration. In the first, the Earth and other planets are individualized; in the seventh, man appears in accordance with biblical tradition. The characteristics and origin of the rocks that constitute the Earth are referred to in this book, and he distinguishes between "original rocks", the result of the consolidation of fused primitive materials or the result of their degradation, granite, sandstones, clays and slates, and "calcareous rocks", which are of organic origin and originated in a marine environment. To these two large groups he adds the "coals", formed by fossilized vegetable remains, and the "volcanic rocks" formed by the consolidation of materials melted in the Earth's interior which emerge to the surface through fissures, a novel idea at the time as other authors considered that volcanoes were created by the combustion of underground coal deposits that melted the surrounding rocks. As important as all Buffon's observations, many of which

were very advanced for the time, is his capacity for dissemination, which without doubt is helped by the quality and clarity of his language. It is not surprising therefore that his ideas are amply represented in the *Encyclopédie*, although he does not seem to have collaborated.

The French geologist Nicolas Desmarest (1725-1815) studied the volcanic area of Auvergne in the Central Massif of France and considered that the basalts were the result of the solidification of lava emitted from volcanoes that were already extinct. Although his works did not appear until a few years later, his ideas on volcanism and the internal structure of the Earth can be found in the *Encyclopédie*, as here he expounds his ideas which would later be published separately.

Looking through the articles of the *Encyclopédie* dedicated to Earth sciences we can confirm the mix of tradition and modernity, which characterized the *Encyclopédie*, and without doubt is a result of the various numerous authors who took part in its redaction, who were in many cases unknown.

The articles of the *Encyclopédie*

The first thing that catches our attention when reviewing the articles dedicated to the Earth sciences in the *Encyclopédie* is that the word "geology" does not appear in them and the content is referred to as physical geography, although the term "Geology" is cited in the classification table of "human knowledge" as "the science of the continents". At this time geology was in its infancy and had furthermore been discredited by the "theories of the Earth" published by the aforementioned scientist-theologians Burnet, Woodward and Whiston, who tried to explain its history and structure based on the teachings of the Bible. The descriptive and applied aspects of the Earth sciences were considered to be mineralogy and mining, without any relation whatsoever to geology. This idea, which Desmarest defended, is that which governed the redaction of the *Encyclopédie*. Only a few years later, when he collaborated on the *Encyclopédie méthodique* (1798), he qualified this opinion and distinguished geology from "the theories of the Earth" (Laboulais-Lesage 2002).

In the following pages we will analyze the terms related to the Earth sciences except mineralogy and metallurgy, the greater part of which was redacted by Holbach, who relied heavily on the works of Agricola (1494-1555) and Wallerius (1709-1785), considered as being the founders of mineralogy. We will not analyze some articles which refer to the Earth sciences but

have no content, such as "*Antidiluvien*" (antediluvian), "*Limon*" (silt), "*Revolutions de la Terre*" (revolutions of the Earth), "*Pierres*" (stones), "*Rocher, Roche, Roc*" (rock), "*Charbon*" (coal) or "*Fontaine*" (fountain), the last redacted by Desmarest. Instead of following an alphabetic order, the terms are grouped thematically.

***Géographie Physique* (Physical Geography)**

It is an article of great length (26 pages) and content. Desmarest, its author, defines it as the "reasoned description of the great phenomena of the Earth and the consideration of the general results deduced from local and particular observations", and apart from it including meteorology, hydrology, climatology and oceanography, its content is the same as that accepted until the beginning of the twentieth century. A large part of the article is dedicated to the explanation of the methodology, maintaining that this study should be based upon "the observation of the facts", in order to be able to "classify the phenomena" and deduce "some general principles". As such it has a somewhat "Newtonian" vision of science.

It extensively describes the terrestrial and coastal morphology, referring only to the continents of the Old World and New World, as he considers that the austral and arctic lands are "not well known"; he also cites the alignment of the mountain ranges, and, with much less detail, the ocean floor. In the analysis of the Earth's crust he recognizes that "it is constituted of beds or layers of constant thickness", as Steno had already stated, but he does not only analyze one plain, as did Steno in the case of Tuscany, but also the mountain ranges, and recognizes that there the strata are not always horizontal but slanted or folded but he does not trouble himself with the cause of these deformations. He describes the "cracks" in the rocks, but neither does he try here to shed light on the cause. In the study of rocks he follows the method of classification proposed by Buffon, dividing them into "vitrifiable substances" and "calcareous substances", and similarly when he refers to fossils and "petrifications". On the other hand his description of mineral beds is more original, which he considers to be the result of the "degradation of the rocks".

It is very interesting to note the relation he expounds between the erosion of the mountains and the sedimentation on the plains, and the description he makes of "the extraordinary layers of gravels and sands" as fluvial deposits or slope debris without recourse to the Flood to explain their origin, as was

common at the time. As might be expected, given the investigations being carried out in Auvergne, the results of which would be published some years later; he also refers to active and extinct volcanoes as well as submarine volcanoes, the origin of many islands, and recognizes their relation with earthquakes. The last part of the article is dedicated to meteorology, climatology and hydrology, considering that all this forms part of "the objects of concern to Physical Geography". The final reflection in which he closes these notes justifies that it is principally descriptive, without putting forward the cause of these phenomena: "The objective of the theories of the Earth is large and awakes more curiosity, but it should not be more than a consequence of a general plan of a very complete Physical Geography". Without doubt Desmarest is thinking of the publications of Burnet, Woodward and Whiston (Laboulais-Lesage 2002).

Volcan (Volcano)

Authored by Holbach (Paul Henri Thiry, Baron de Holbach, 1723-1789), a French philosopher of German origins, who was very familiar with the scientific discoveries of the time, especially in geology, a science which in the Germany of the time was more advanced than in other European countries, and also wrote several articles on chemistry, mineralogy and metallurgy. Along with "Physical Geography" by Desmarest, this article is one of the best of the *Encyclopédie* with regard to geology. In addition to describing volcanic phenomena, he also refers to the Earth's interior, which he supposes to be "filled with substances capable of feeding the fire", which would be the cause of both volcanoes and earthquakes; although he assumes that eruptions would be influenced by water infiltration and notes that the majority of volcanoes are near the sea. His opinion of the consequences of eruptions is reminiscent of the optimism of Voltaire's *Candid*: "Volcanoes should be seen as safety valves of the Earth, or like chimneys through which she gets rid of flammable substances which devour her womb". "Without these agents revolutions far more terrible would be produced than those we see in earthquakes". It is interesting to note the novel reference, for the time, to the volcanoes of Auvergne and the recognition that the lava flows of this region are the result of ancient eruptions. The reference to submarine volcanism is also interesting, and the knowledge of the world that he demonstrates in the great number of volcanoes from different regions which he cites: from the Andes to the islands

of the Atlantic, from the Pacific to the Indian Ocean, as well as those of southern Italy, although he supposes that Africa, of which he no doubt knows little, possesses none.

Lave (Lava)

Holbach gives a detailed description of the lavas of Etna and Vesuvius as well as the destructive effects of the flows, of both ancient and more recent eruptions. He analyzes their different aspects, more compact or sponge-like, and he erroneously supposes that travertine, a calcareous rock is also of volcanic origin. On the other hand, his observation that the basalts of Auvergne are the product of ancient lava flows of volcanoes now extinct was completely right. This was an idea that was still not admitted at the time and Desmarest published it some years later.

Tremblements de terre (Earthquakes)

The interest of this article is in the vision that the author has in the composition of the Earth's interior, as he considers that as well as the central fire, the water and air trapped within the interior are the cause of these movements. Furthermore, the deposits of coal and "bitumen" (that is to say hydrocarbons) as well as the "decomposition of pyrites" and other elements feed the fire, and he proposes various experiments to demonstrate this. He considers that air and especially subterranean water also play an important role in producing sufficient energy for both the earthquakes and volcanoes. Besides a historical study, he writes a long and curious description of the phenomena that accompany, precede or follow an earthquake among which is an accurate reference to the "violent movements of the sea", which nowadays we call tsunamis, and that, as we now know, are caused by earthquakes produced under the ocean floor. His observations about the rapid propagation of earthquakes over long distances are very interesting and he suggests that there is some relation with the direction of the great mountain ranges.

More interesting still is his intuition that these movements are responsible for the changes that have been produced on the planet, which he calls "revolutions", the majority of which he considers very ancient and suggests some of the possible changes that could have been caused, for example that Great Britain was once joined to the European continent or Sicily to the Italian peninsula. He also believes it possible that the Mediterranean, the Caspian and

Black Seas were produced by the action of these "revolutions", and makes reference to Atlantis and the possibility that the Azores, Canary Islands and Cape Verde are the remains of this lost continent. This is evidently inaccurate, but his idea that the internal energy of the Earth has produced changes to the surface is very interesting and in his time was much debated, and in general was accepted that the Earth had remained very much the same since its creation except for the changes produced by the Flood.

Terre (Earth)

This article refers especially to astronomy and contributes little from the point of view of geology to the article of "Physical Geography", with just one interesting reference to the Flood. It cites the work of Woodward (1723) which explains the sedimentary formations in terms of the Flood, describing it as "a hypotheses more ingenious than true" and "a very fanciful idea, seeing as the sedimentary rock strata have been formed over a very long time and by "successive revolutions", that have caused the continents to be covered by the oceans on a number of occasions. This idea of revolutions is very interesting, as he considers it to be connected with the disappearance of some forms of life and the appearance of others. When the revolutions are "local", he supposes them to be originated by earthquakes, volcanoes, the wind and rain, and when they are "general", due to changes in the rotational axis of the Earth. Another novel idea is his vision of erosion-sedimentation: "the waters work continuously in wearing down the elevated regions and filling the depressions".

Déluge (Flood)

Redacted by Diderot, it is a curiously orthodox article with respect to the teachings of the Church, of a style and orientation which is very different from the others which refer to the Earth sciences. Two years previously, the printing and distribution of the first volume of the *Encyclopédie* had been prohibited as it was considered that it defended materialistic and atheist ideas. For this reason the authors were very careful in the redaction of this article for fear that the censors would not allow its publication.

It is based on an article of Nicolas Boulanger which was never published (Roger. *L' Histoire Naturelle et les Sciences de la Vie*, in Ricci 1978), these texts are reproduced inside quotation marks

and represent nearly 90% of the total, the reason for which this article is sometimes attributed to this author. Boulanger (1722-1759) was a civil engineer and friend of Diderot, and was as much interested in psychology and religion as he was in geology, and was a believer in the Flood; according to him it had a profound effect on the human psyche and that the terror that was conserved in the human subconscious made despotism possible. The article reviews all the floods that are cited in mythology and ancient history, and he considers that the existence of marine fossils on the continents and the modelling of the reliefs are proof of this; he also refers to the works of Burnet and Whiston to understand the causes, but he recognizes that it is difficult to explain the origin of such an enormous quantity of water necessary for a universal flood and to explain that this would have produced the disappearance of all humans and other living creatures that did not seek refuge in Noah's Ark. He also cites the works of Descartes (1596-1650) and Steno (1669), who do not accept the universality of the Flood nor that it was the cause of the existence of marine fossils on the continents, but considers, citing Boulanger once more, that "every good Christian should reject the objections that oppose it, which is not as difficult as it might seem." In short, it is an article lacking in both the scientific vision of the encyclopaedists and the critical spirit of the Enlightenment. Without doubt Diderot redacted it thinking that it would be one of the articles the censors would review, looking for heresies that would provide motives to once more prohibit the *Encyclopédie*. It should not be forgotten that in those days to deny the existence of the Flood, just as it is described in the Bible, was to confront the religious authorities.

Fossile (Fossil)

In those days the designations "fossil" and "mineral" were used interchangeably to refer to all the substances found in the interior of the Earth. This article distinguishes between two types of fossil, as Woodward (1723) had previously done: the "native fossils" formed in the Earth, i.e. the minerals; and the "extraneous ones", i.e. the remains of plants and animals that have accidentally been buried and "petrified". Evidently, it is the second group to which we refer to here. An interesting observation is that the fossils of animal origin are almost always of marine organisms that nowadays only live in climates which are very different from those in which their fossilized remains were found (Indian sea and seas of warm

countries), and moreover some of them, such as belemnites and ammonites, correspond to animals no longer living.

In a review of the different explanations used in an attempt to explain the origin of fossils, he refers to the theories of Burnet and Woodward, and without disputing the existence of the Flood, "out of respect for the Holy Scriptures" (*On ne peut pas douter de la réalité du Déluge, de quelque voie que Dieu se soit servi pour opérer cette grande révolution, mais il paroi que, sans s'écarter du respect dû au témoignage des Saintes Ecritures, il est permis à un naturaliste d'examiner si le Déluge a été réellement cause des phénomènes dont nous parlons*), maintains that this cannot be the true explanation, due to different stages of their formation and the difficulty concerning the way in which the terrestrial animals have been able to disperse into the different parts of the world. In agreement with Desmarest, he thinks that a scientist should devote himself to the study of nature, instead of constructing hypotheses about the origin of the phenomena. His observations on limestone and marble are interesting, rightly considering them to be formed by petrified organic remains.

Montagnes (Mountains)

Redacted by Holbach, although it has sometimes been attributed to Desmarest, it is principally a descriptive article and distinguishes the "ancient or primitive mountains" formed at the same time as the Earth and consisting of very hard rocks and massive structure, from the "recent mountains" made up of sedimentary and fossiliferous rocks (clay, sands, chalk) that would have been formed by "revolutions" due to the interior fire of the Earth or floods. He contributes different opinions on the origin of the mountains and refutes the ideas of Burnet and Woodward, whereby terrestrial mountains were formed by the actions of the Biblical Flood, although he considers that they could have been formed by violent floods. He also has some very curious ideas, stating that the rotation of the Earth could cause a flattening of the poles resulting in these relieves and also that they could be a "result of the consolidation of the fluid materials which at first constituted the globe".

The ancient mountains would be the highest; they would be formed by very hard rock and would contain veins of minerals. Amongst these he cites the Alps, the Pyrenees, the Apennines, the Carpathian Mountains, the Appalachians and the

Andes. The recent mountains would be formed by unconsolidated materials containing sea shells, which would be evidence that they had originated by the action of water, not mineral veins but layers of coal and iron oxides, rock salt and hydrocarbons. He considers volcanoes to be a special case.

Conclusions

The *Encyclopédie* has been the object of numerous analyses, but historians of science have devoted little attention to it (Blom 2004, Pons 1986) and geologists and historians of geology have practically ignored it. The article by Roger (Ricci 1978) is therefore very interesting, although the Earth sciences only merit a brief but accurate mention.

Most of the articles of the *Encyclopédie* on Earth sciences are dedicated to mineralogy or metallurgy and were written by Holbach, who collected together the works of Agricola and Wallerius. Instead of reviewing these articles, it is more interesting to analyze the new contributions to the history and structure of our planet that are described principally in "Physical Geography", redacted by Desmarest, and "Volcanoes", written by Holbach, as well as "Earthquakes" and "Fossils". These authors had an intuitive idea of what would later be explained by Hutton, Werner and Lyell, and break with the tradition existing at the time of the geologist-theologians Burnet, Whiston and Woodward, who tried to explain the history of the Earth using the Bible. By contrast, Desmarest and Holbach contend that the Earth has changed and continues to change by action of its internal energy, and suggest an age for it much older than that proposed at the time. In these articles, without denying the existence of the Biblical Flood, they minimize the action it could have had on the origin of fossils and terrestrial modelling.

This commitment is clearly expounded by Diderot in the article devoted to the word "Encyclopaedia" when he says that its function is "to shake off the yoke of authority and example to hold to the laws of reason" and also Desmarest in the article "Physical Geography", when he indicates what should be the methodology employed in this science. He defines it as "the reasoned description of the great phenomena of the Earth and the consideration of the general results deduced from local and particular observations, methodically combined and brought together", an empirical knowledge based on close observation of the terrain, the selection of the relevant data, rationally and critically elaborated, disregarding any pre-established idea or argument from authority or religious belief:

a modern approach to the task of the scientist, very different from that of the geologist-theologians who studied the Earth with the biblical narrative in mind.

To sum up, although this work did not make a great contribution to the fields of Earth sciences, it represented a new approach to them, before the eighteenth and nineteenth centuries when this scientific approach was consolidated by Hutton and Lyell. It is also very important in helping us to assess the environment in which the Encyclopaedists moved and better appreciate what their critical spirit and fight against dogmatism represented in the creation of modern thought.

Acknowledgements

I am grateful to the librarians of the Colegio de España, Cité Internationale Universitaire of Paris and the Ateneu Barcelonés of Barcelona. I would also like to extend my grateful thanks to Professor Durand-Delga for his teaching and suggestions in the field of the history of the study of geology.

References

- Agricola (Bauer), G. 1556. *De re metalica* 12 v. Basilea Trad H.C. Hoover and L.H Hoover, Ed. Dover. Londres. 1986.
- Agricola (Bauer), G. 1544. *De ortu et causis subterraneorum*. Basilea.
- Agricola (Bauer), G. 1546. *De natura Fossilium*. Basilea. Trad. 2004 Bandy, Ed Dover. Londres.
- Blom, Ph. 2004. *Encyclopédie*, Harper Collins. Londres. Spanish trans. Anagrama. Madrid 2007, 460 pp.
- Buffon, G. L. Leclerc Comte de, 1778. *Les Époques de la Nature*, 2 v. Paris.
- Buffon, G. L. Leclerc Comte de, 1749-1788. *Histoire Naturelle, générale et particulière, avec la description du Cabinet du Roy* (44 v.) 1^{er} vol. (1749). Aux Deux-Ponts. Chez Sanson & Compagnie (1786). 290 pp.
- Buffon, G. L. Leclerc Comte de, 1749-1788. *Histoire et Théorie de la Terre*, Paris. (Madrid, 1844).
- Burnet, T. 1680. *Telluris Theoria Sacra*. London, Kettilby, 306 pp.
- Descartes, R. 1723. *Les principes de la Philosophie. Ecrit en latin et traduit en français par un de ses Amis*, Ed. Compagnons des Librairies. Paris. Quatrième Partie, De

- la Terre* (pp. 364-589, pp. 593-600). Biblioteca Nacional de Catalunya (www.bnc.cat).
- Desmarest, N. 1798. *Encyclopédie méthodique. Géographie physique, Dictionnaire de l'Académie française*. Paris. Vol. 7, pp. 613-626.
- Diderot, D. and d'Alembert, J.R. 1777-1779. *Encyclopédie ou Dictionnaire raisonné des sciences des arts et des métiers, par une Société de gens de lettres*. 3rd ed. 36 vol. Geneva (www.bnf.fr).
- Diderot, D. and d'Alembert, J.R. English translation. University of Michigan (<http://quod.lib.umich.edu/d/did>).
- Furetière, A. 1694. *Dictionnaire universel contenant généralement tous les Mots François, tant vieux que modernes, et les termes de toutes les sciences et des arts*. Ed Arnout et Reinier Leers, La Haye, 3 vol. non paginés.
- Laboulais-Lesage, I. (2002) Les méthodes de la Géographie physique selon Nicolas Desmarest. *Travaux de Comité Français d'Histoire de la Géologie* (3 s.). T. XVI (19 juin 2002). Paris. p. 16.
- Lehmann, J.G. 1756. *Kurze Klassifikation und Beschreibung der verschieden Gebirgsarten*. p. 28. Berlin.
- Ricci, F.M. (Ed.) (1978), *Encyclopédie. Diderot et d'Alembert*, 18 vol. (12 vol. pp. 11-14, 5 vols. selected art.). Milano 1^{er} vol "Essais et notes" Prologue J.L. Borges. pp. 11-14. L'Histoire naturelle et les sciences de la vie, J.Roger. pp 243-267. Feuilles I-XVIII. Paris.
- Steno, N. 1667. *Canis carcharia dissectum caput*. Florencia. SCHERZ, G. (1969) Steno. Geological Papers. Odense University Press.
- Steno, N. 1669. *De Solido intra Solidum Naturaliter Contento Dissertationis Prodromus*. Florencia. From G. Scherz, edit. (1969), «Steno. Geological papers». Biobliotheca Universitatis Hauniense, Acta Historica Scienciarum Naturalium et Medicinalium, Copenhagen, vol. 20, 133-217.
- Trévoux. 1704-1771. *Dictionnaire universel François et Latin. Trévoux*. Vol. 2, 1932 pp.
- Wallerius, J.G. 1753. *Minéralogie ou Description Générale des Substances du Regne Mineral*. [Mineralogia, eller mineralriket indelt och beskrifvet]. (Tr. d'Holbach). Ed. Durand - Pisot, Paris, 2v. 589 pp.
- Whiston, W. 1696. *A New Theory of the Earth, From its Original, to the Consummation of All Things, Where 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*. London, Benjamin Tooke.
- Woodward, J. 1723. *An Essay toward a Natural History of the Earth and terrestrial Bodies, especially minerals &c*. 3rd ed. London.

Recibido: enero 2014

Revisado: noviembre 2014

Aceptado: junio 2015

Publicado: julio 2016