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Descartes's Geology, or How to Access the Earth's Past Through Reason

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Abstract: This study aims to recover the significance of Cartesian thought for the History of Geology. To this end, Descartes's thesis is examined from two perspectives: the emergence of a new way of interpreting the planet—referred to as the Terraqueous Globe—and the Cartesian Natural Philosophy within the broader context of seventeenth-century mechanism. The analysis shows that Descartes presents a coherent theory, transforming the Terraqueous Globe into an object of scientific inquiry by interpreting it mechanically and attributing to it a past accessible to reason. Such a proposal did not go unnoticed by his contemporaries and was able to influence philosophers and naturalists in the decades that followed.

Keywords: Descartes; History of Geology; Mechanical Philosophy; Natural Philosophy; Terraqueous Globe.

A Geologia de Descartes ou como acessar o passado da Terra pela Razão

Resumo: Este trabalho tem como objetivo resgatar a importância do pensamento cartesiano para a História da Geologia. Assim, sua tese foi analisada a partir de duas vertentes: a emergência de uma nova forma de se interpretar o planeta, denominada de Globo Terráqueo; e a Filosofia Natural cartesiana no contexto do mecanicismo seiscentista. Como resultado, observa-se que Descartes apresenta uma teoria coerente, tornando o Globo Terráqueo um objeto de investigação científica ao interpretá-lo de maneira mecânica e lhe atribuir um passado acessível à razão. Tal proposta não passou despercebida por seus contemporâneos, sendo capaz de influenciar filósofos e naturalistas nas décadas seguintes.

Palavras-chave: Descartes; História da Geologia; Filosofia mecânica; Filosofia Natural; Globo Terráqueo.

Introduction

Extensively discussed within Philosophy and the History of Science, the work of René Descartes (1596–1650) is widely examined for its contributions to Epistemology and to the histories of Physics and Biology. In the history of Geology, however, we find the opposite situation. In general, Cartesian reflections devoted to understanding the Earth are traditionally classified among the well-known “Theories of the Earth” produced from the late seventeenth century onward, whose main theoretical and methodological references are found in works shaped by English millenarian Protestantism. It is precisely because of this association, as well as the predominantly theoretical character of Descartes' proposal, that authors such as Ellenberger (1988; 1994), Oldroyd (1996), Balan (2011), and, to a lesser extent, Gohau (1987; 1990) interpret Descartes' theses about Earth as mere conjecture, incapable of offering significant contributions to the emergence and development of modern Geology.

However, as will be shown throughout this article, when Descartes' discussion is analyzed within the scientific context in which it was embedded—seventeenth-century science—a different picture emerges. Descartes presents a theory of the formation of the Earth and of the dynamics of its main phenomena that is genuinely innovative for its time. In it, we find a perspective on the planet that departs from the purely astronomical view, adopting instead the new concept of the planet Earth that began to emerge at the end of the sixteenth century in place of the medieval conception: the Terraqueous Globe. In this sense, Descartes may be considered the first author to employ this new conceptualization of the planet, which served as the starting point for the development of a new theory about Earth grounded in mechanical principles and therefore aligned with the emerging new science—that is, with mechanistic Natural Philosophy.

Thus, just as Cartesian philosophy significantly influenced his contemporaries across various fields of knowledge, his proposal for understanding the Earth also exerted considerable influence. Many Cartesian theses appear in the numerous theories that sought to explain the formation and development of the Earth and its main surface structures, such as mountains, hydrographic systems, and the ocean

floor¹. His ideas remained central to these discussions until the first half of the eighteenth century, when they began to be definitively superseded and fell into disuse².

Given this context, the present article seeks to recover the importance of the Cartesian proposal for the history of geological knowledge by examining two issues that, although often overlooked by historians of geology, allow us to reassess Descartes' significance when analyzed more carefully. The first concerns the emergence of a new way of interpreting the planet - the Terraqueous Globe - which was capable of displacing the Aristotelian dynamics of the spheres of the elements in explaining terrestrial relief, and which Descartes used as a central component of his theory of the planet. The second concerns understanding his theory about Earth, as well as his Natural Philosophy, within the turbulent scientific and philosophical context of the seventeenth century. This, in turn, enables us to grasp the importance and innovative character of his proposal for the period. With this in mind, we begin our discussion with the first issue, revisiting the millennia-old thesis that preceded the emergence of the Terraqueous Globe as a framework for understanding the planet: the Sublunar World.

When planet Earth did not exist: the Sublunar World and the incoherent existence of the continents

Throughout Antiquity and the Middle Ages, the Earth was the subject of numerous theoretical constructions that generated extensive debates and controversies³. Traditionally, many of these discussions are presented through the lens of the history of Astronomy, whose focus naturally falls on themes and disputes directly related to that field. Thus, among the most frequently cited examples concerning interpretations of the Earth, we find questions about its spherical shape, its position at the center of the Cosmos, its immobility, and the fact that it was not considered a true planet within ancient and medieval philosophy. Given the broad influence of the history of Astronomy - which emphasizes the crucial role of new

¹ Santos (2024).

² Santos (2024).

³ For a better understanding of these discussions, see Duhem (1914; 1958).

conceptions of the heavens in the emergence of modern science⁴ - these topics have become standard reference points and are widely reproduced in books and various media.

However, although these astronomical themes are undoubtedly important for understanding historical conceptions of the Earth, they represent only part of the story. As we shall see, there existed a vast debate—largely forgotten by the History of Science—that sought to explain the dynamics of the Earth's surface within the Aristotelian Cosmos. In this context, while the conception of the Earth as a set of concentric spheres composed of the four primordial elements (earth, water, air, and fire) posed no major difficulties for ancient and medieval Astronomy in its attempt to account for the heavens, this same model rendered the existence of mountains and continents entirely unintelligible. In other words, the Aristotelian physical structure of the world made the very existence of terrestrial relief impossible.

In this way, to understand the emergence of the Terrestrial Globe and its use by Descartes within the new Natural Philosophy, it is therefore essential to outline the Aristotelian Cosmos and its conception of the Earth—namely, the Sublunar World⁵—as well as the most successful medieval attempt to resolve its contradictions: the theory developed by Jean Buridan (1301–1358).

Thus, in Aristotelian thought, the Cosmos—finite and eternal—is divided into two distinct regions: the Sublunar World and the Celestial or Supralunar World. This division is intrinsically linked to Aristotle's understanding of matter, which can assume four elemental forms: earth, water, air, and fire. Each element is composed of a pair of primary qualities: earth is dry and cold; water is cold and moist; air is moist and hot; and fire is hot and dry⁶. Through combinations of these elements and their qualities, all natural bodies are formed and undergo change, whether understood as alteration or motion⁷.

Aristotle also posits that each element has a natural place—a region to which it tends in the absence of impediments⁸. These natural places take the form of concentric spheres arranged according to the relative heaviness of the elements:

⁴ Grant (2007); Belhoste (2016).

⁵ In this article, we will limit ourselves to addressing only the Aristotelian perspective on the subject, given the predominance of Aristotle's thinking in medieval thought.

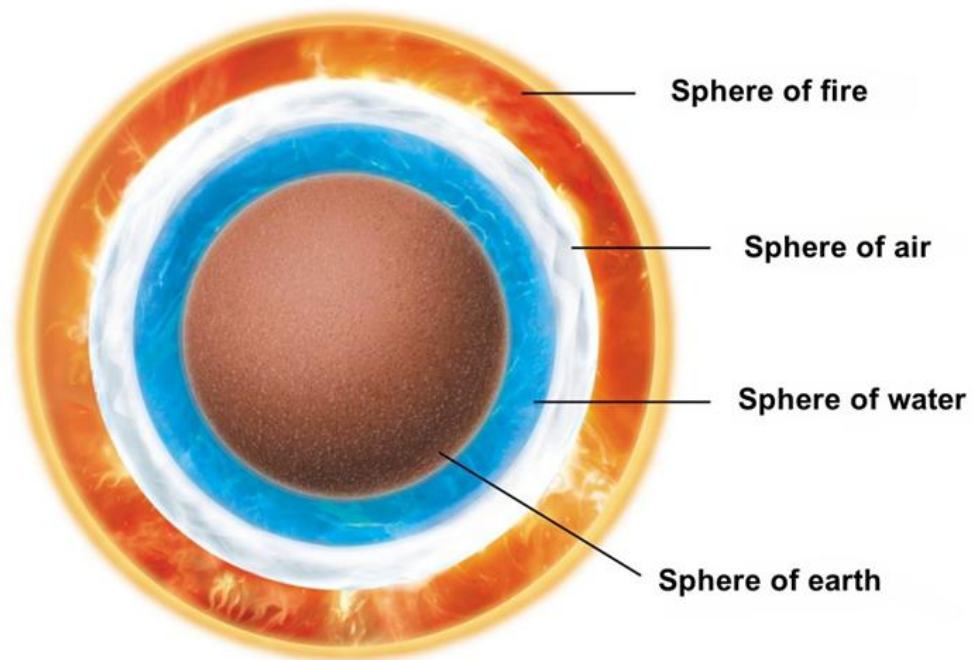
⁶ Nadler (1998); Chauí (2018).

⁷ Grant (2007); Chauí (2018).

⁸ Duhem (1958); Grant (1994); Chauí (2018).

earth at the center, followed by water, air, and finally fire (Figure 1). This arrangement not only describes the structure of the physical world but also explains natural motion: a stone falls because it is composed primarily of earth, which seeks its natural place at the center of the Cosmos; fire rises because it seeks the outermost sphere, and so on⁹.

Figure 1 - Natural place of the elements according to Aristotle.



Source: Deschamps and Noël (2020, adapted by us).

On the other hand, change understood as the alteration of a given state of matter is explained through the pair of qualities associated with the elements that compose it. As previously noted, each element possesses at least one quality that stands in direct opposition to that of another element. The element water, for instance, characterized by the qualities of cold and moist, is directly opposed to the element fire, which exhibits the qualities of hot and dry. Fire, however, shares only one opposing quality in relation to earth, which is cold and dry. Thus, when an element loses one of its qualities and adopts another, it transmutes into a different element. In other words, if the element fire were to lose the quality of hot and acquire the quality of cold, it would be converted into the element earth¹⁰.

⁹ Duhem (1958); Grant (1994); Chauí, (2018).

¹⁰ Grant (1994).

Aristotle further maintained that the Earth's surface was subject to continuous change. According to him, land and sea alternated eternally in a slow, gradual cycle without catastrophic events¹¹. In this way, the emergence of marine fossils on land did not indicate a universal drying of the world, as some philosophers claimed, because other regions were simultaneously being submerged in a kind of compensatory process¹². Thus, the terrestrial surface of the Sublunar World, in the Aristotelian view, would be in a state of perpetual equilibrium—a steady-state system¹³.

In contrast, if the Sublunar World is characterized as the realm in which change and becoming prevail, the Celestial World occupies a completely opposite condition. Composed of a set of eight spheres, which are concentric with the spheres of the elements, this region of the Cosmos is unfamiliar with generation and destruction¹⁴. The celestial bodies located there are regarded as immutable and, in the case of the planets, capable of performing only a single motion—considered perfect and divine—namely, circular motion¹⁵. In light of this, Aristotle concludes that the celestial region could not be composed of the same elements that constitute the sublunar realm, since, as we have seen, they exhibit entirely different behaviors. For him, this celestial region must be constituted by a completely distinct element, one devoid of contrary qualities and therefore incorruptible¹⁶. This fifth element was designated by Aristotle as aether.

However, although this model works relatively well for astronomical and physical purposes for which it is intended, it contains a glaring contradiction regarding terrestrial relief. If the natural place of earth is beneath the sphere of water (Figure 1), then the existence of continents and mountains—protruding into the sphere of air—should be impossible. In a strict Aristotelian world, all land should be submerged. In fact, if this Aristotelian model is an accurate portrayal of how nature works, all living beings we know should be marine, making the existence of terrestrial life itself impossible.

¹¹ Duhem (1958).

¹² Duhem (1958).

¹³ Gohau (1987); Ellenberger (1988).

¹⁴ Grant (1994).

¹⁵ Grant (1994; Chauí (2018).

¹⁶ Grant (1994; Chauí (2018).

Aristotle offered no solution to this contradiction, and the problem did not escape the attention of ancient and medieval thinkers¹⁷. Over the centuries, numerous explanations were proposed—from theories of cyclical destruction and restoration of relief to claims that God miraculously held back the waters to preserve dry land¹⁸. This debate persisted for nearly a millennium across Greek, Arabic, and medieval scholarship without reaching a definitive resolution¹⁹.

Only in the fourteenth century did Jean Buridan (1301-1358) offer a solution that gained broad acceptance²⁰. Drawing on ideas from Alexander of Aphrodisias (198-209 d. C.), Buridan argued that the Cosmos had two centers: a geometric center and a center of gravity. For him, although these two centers coincide with each other, the true center of the Cosmos would be that of gravity, with the elements distributed around it according to their respective weights²¹. As a result, we have the classic formation of the Aristotelian Sublunar World, with its concentric spheres of elements, except for the sphere of Earth, which is seen as eccentric to the center of the Cosmos. Buridan explains this anomaly through the composition of this sphere, considered to be a compound formed by an agglomeration of materials of different densities and distributed irregularly throughout its entire body. It is precisely this great heterogeneity that would promote a misalignment between the geometric and gravitational centers of this sphere with those of the Cosmos, which is the reason for its eccentricity and why we have a terrestrial surface (Figure 2).

¹⁷ Duhem (1958).

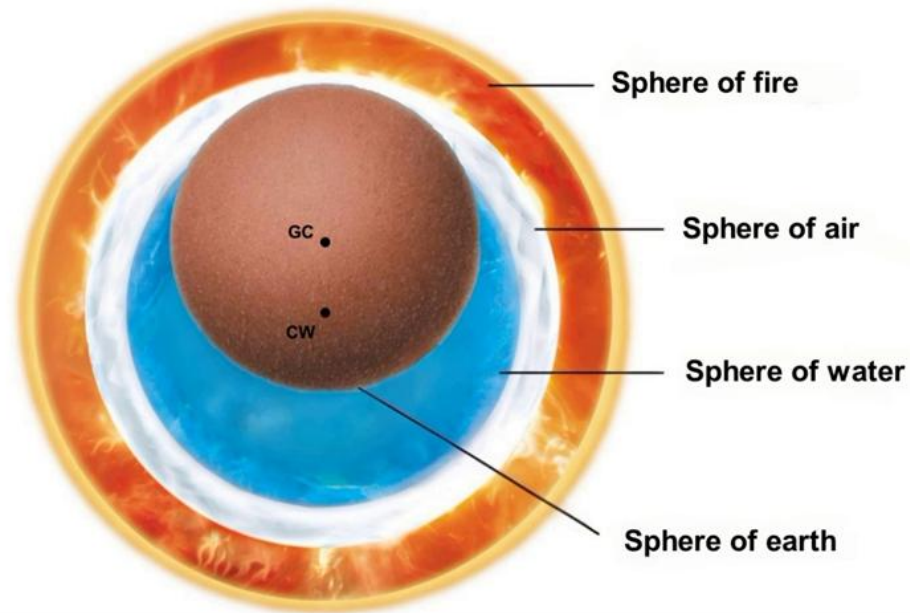
¹⁸ Duhem (1958).

¹⁹ Duhem (1958). Duhem (1958) also demonstrates that this was one of the ways in which the medieval world explained the occurrence of the Flood. According to this view, God would continually maintain a kind of damming of the ocean waters, preventing them from invading the earth's surface. The Flood, therefore, would have been just a brief moment when God suspended this containment.

²⁰ Duhem (1958); Randles (1994).

²¹ Duhem (1958).

Figure 2 – Model of the arrangement of the spheres of the elements adopted by Jean Buridan.



Source: Deschamps and Noël (2020, adapted by us). The GC point is the Geometric Center of the earth sphere. The CW point is the Center of the World or center of gravity. Note that the center of the sphere of earth does not coincide with the center of the other spheres of the elements and that it is impossible for other emerged lands, or continents, to exist around the sphere of earth.

Aware of erosion's effects, Buridan proposed a compensatory mechanism: sediments eroded from continents and carried by rivers to the oceans would accumulate around the part of the earth's sphere that is submerged. Consequently, given this new distribution, the center of gravity of this sphere would undergo a change, readjusting itself in relation to the center of gravity of the World, to be closer to it. As a result, the continents would be slowly lifted, as in an isostatic process²² and saved from an irreversible end. This cycle, he argued, continued indefinitely²³.

Therefore, by proposing this compensatory system for terrestrial relief, Buridan succeeds in resolving, at once, the contradiction within Aristotelian natural philosophy between a terrestrial surface conceived as being in equilibrium between land and sea and a cosmological model in which that very surface is considered

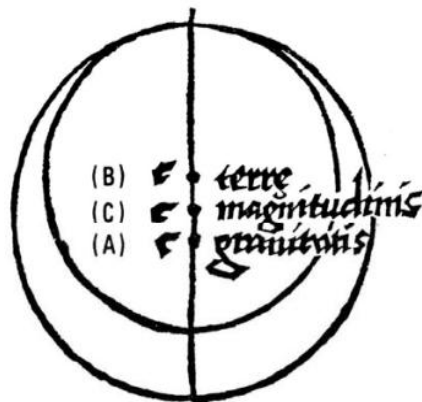
²² Ellenberger (1988).

²³ Duhem (1958).

nonexistent²⁴. Moreover, the continents—until then regarded as an anomaly within the Aristotelian system—come to be understood as a moment, a phase of disequilibrium within a broader context of dynamic balance in which the Sublunar World is situated.

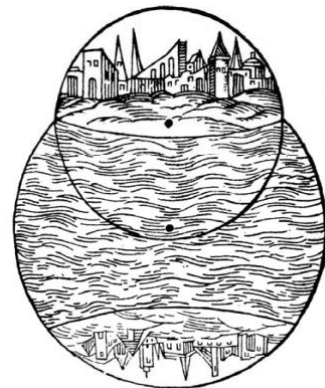
Although criticized in certain respects by contemporaries such as Nicolas Oresme (1323–1382) and Pierre D'Ailly²⁵ (1351–1421), Buridan's thesis prevailed within the Faculty of Arts in Paris and in other European universities, including Oxford²⁶. His theory also appeared in virtually all cosmographical works of the fifteenth century²⁷ and, in the following century, was taught and defended by the Jesuits until it was later contested by them²⁸ (Figures 3 and 4). The wide acceptance and circulation of his ideas constitute an important indication that his proposal offered a genuinely satisfactory solution to the age-old dilemma of the emergence of land and its relation to the spheres of earth and water.

Figure 3 - The spheres of water and earth debated by the German humanist Gregor Reisch (1467-1525) in his *Margarita Philosophica* (1504).



Source: Randles (1994, p. 57). Where A and B represent respectively the centers of gravity and geometry of the sphere of Earth, and C the center of the World.

Figure 4 - Buridan's thesis discussed by Jesuit priest Christophe Clavius (1538-1612) in his book *Sphaera Ioannis Sacrobosco* (1593).



Source: Randles (1994, p. 67). Points referring to the geometric centers of the Earth's sphere and the World.

²⁴ For more details on Buridan's thesis, see. Duhem (1958). A summarized version in Portuguese can be found in Santos (2024, p. 114-129).

²⁵ According to Duhem (1958) and Grant (1994), the main objection to Buridan was the displacement of the earth sphere. For these authors, it was absolutely immobile, and it was impossible to admit that it could perform any kind of movement, however small and slow it might be.

²⁶ Duhem (1958).

²⁷ Vogel (2006).

²⁸ Duhem (1958).

Nevertheless, all of this was about to change with the rise of the new Astronomy and, above all, with the fusion of the spheres of earth and water made possible by the Great Navigations, which would give rise to a new object of scientific inquiry at the end of the Renaissance: the Terraqueous Globe, or the Earth as we know it today.

A New Scientific Object: The Terraqueous Globe and the Birth of the Modern Earth

In an influential article on the history of Geology, Roger (1973) argues that the new discussions about the Earth that emerged from the seventeenth century onward—grouped by him under the title “Theories of the Earth”—were the direct result of the new Astronomy: “Without the Copernican revolution, there would therefore, it seems, be no theory of the Earth²⁹.” This perspective is adopted by virtually all authors who examine the history of Geology within the context of the so-called Scientific Revolution³⁰. Indeed, the new Astronomy brought about profound changes and immense ruptures in the traditional ways of observing, evaluating, and describing the heavens. In this long process, the so-called World of Aristotelian cosmology was redefined as a planet, yielding its place to the Sun as the center of the universe and of planetary orbits in the new Solar System, thereby dismantling the former hierarchy between the Sublunar and Celestial worlds.

However, this is only part of the story. For the Earth to emerge as a planet in the sense we understand today, another development was required. Driven by the Great Navigations and their cosmographers, the discovery of lands south of the Equator was largely responsible for overturning Buridan's thesis. Throughout the sixteenth century, with the mapping of the Brazilian coast and the circumnavigation of the globe, it became clear that the vast newly discovered landmasses were not isolated islands, but true continents situated in the Southern Hemisphere³¹. This fact rendered not only Buridan's thesis untenable but also the very notion of the spheres as independent bodies.

²⁹ Roger (1973, p. 29).

³⁰ We can cite Gohau (1990), Ellenberger (1994), Rappaport (1997), Oldroyd (1997), among others.

³¹ Randles (1994); Besse (2003).

In this context, the sixteenth century witnesses a subtle merging of the terrestrial and aquatic spheres, whose cosmographic representations begin to depict them as a single sphere encompassing both elements, though still situated within the framework of the Aristotelian Cosmos³². This development can be observed in the illustration from “Cosmographicus liber” (Cosmographic Book), published in 1524 by the cosmographer Peter Apian (1495–1551), in which this configuration is clearly visible³³ (Figure 5). The same tendency can also be identified in the works of other cosmographers, such as Finé Oronce (1494–1555), who, alongside Apian, is regarded as a key reference for sixteenth-century cosmographic treatises³⁴. His 1549 book “Le sphere de monde: proprement dicte Cosmographie” (The Sphere of the World: Properly Called Cosmography) likewise reflects this shift (Figure 6). This represents a significant change when these images are compared with Figure 1.

Figure 5 - Representation of the medieval cosmos by Peter Apian (1524).



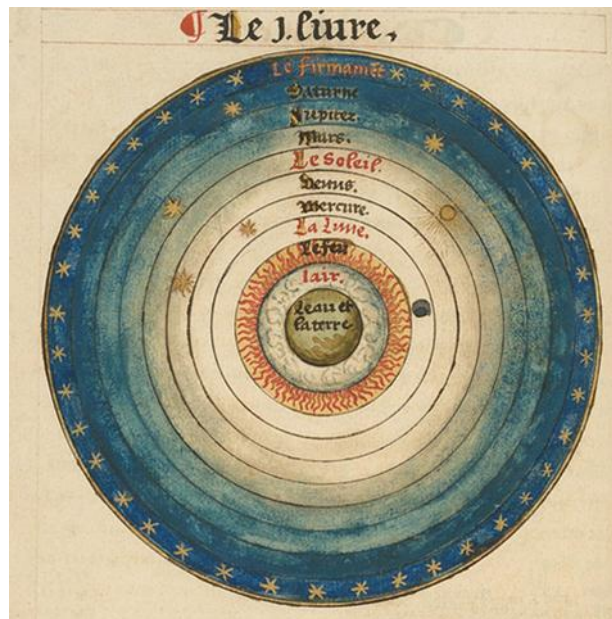
Source: Apian (1524, p. 6). Note the merged spheres of water and earth in the center. This image can also be found in Besse (2003, p. 17), although the author uses a 1584 edition of Apian's work.

³² Randles (1994); Besse (2003).

³³ Besse (2003).

³⁴ Besse (2003).

Figure 6 - Representation of the medieval cosmos by Oronce Finé (1549) with the spheres of water and earth fused together.



Source: Finé (1549, p. 9). Note the spheres of water and earth fused in the center.

This new understanding of the Sublunar World rendered Buridan's subtle mechanistic framework obsolete and, with it, the notion of multiple centers for the spheres. It is no mere coincidence that Copernicus devoted an entire chapter of his renowned "On the Revolutions of the Heavenly Spheres" to refuting the Aristotelian perspective on this matter and to incorporating the new cosmographical and maritime considerations into his defense of heliocentrism³⁵. In this regard, Copernicus (2014, p. 21), in the suggestively titled chapter "How the Earth Forms a Single Globe with the Water", states:

Some claim that the Earth protrudes to a certain extent because its displacement is not everywhere proportional to its weight, since it is full of cavities, and its center of gravity is not the same as its geometric center. But they are mistaken out of ignorance of Geometry, forgetting that the water could not be even seven times greater and leave any part of the Earth dry unless it [sphere of earth] were to withdraw completely from the center of gravity and give place to the water, as if the latter were heavier. [...]. It follows that there is no difference between the Earth's center of gravity and its geometric center.

³⁵ Randles (1994); Besse (2003).

It is with this new conceptualization of the spheres of water and earth—aligned with the new perspectives brought forth by Astronomy—that a new term emerges to designate our planet. At first, it would receive the name of Terraqueous Globe, a term coined from the combination of two Latin words, *terra* (earth) and *acqua* (water), intended precisely to express the idea of a single globe composed of both earth and water³⁶. This conceptual innovation was first proposed by the French Jesuit priest Georges Fournier (1595–1652) in his 1643 work “Hydrographie” (Hydrography). However, Fournier did not provide a definition for the term, leaving it to his compatriot and fellow Jesuit Philippe Labbé (1607–1667) to offer one in his “Géographie Royale” (Royal Geography), published in 1646, where he writes: “Geographers divide into various circles or parts the convex surface of the Terraqueous Globe (thus do the new masters of this illustrious science speak more elegantly to express the Earth and the Water together at the center of the world) [...]”³⁷.

In light of the foregoing, it becomes evident that, by the end of the Renaissance, not only the heavens were being redefined, but the Sublunar World itself. Astronomers, navigators, cosmographers, and later geographers brought about its conceptual implosion while simultaneously constructing a new object of scientific inquiry: the Terraqueous Globe. Within this new context, the first theory to employ this new model—and to be widely discussed in European intellectual circles, proving as innovative as Buridan’s had been for understanding this truly new world—was precisely the one proposed by the French philosopher René Descartes.

The Terrestrial Globe from a Mechanistic Perspective: René Descartes’ Theory about Earth

Among Descartes’ works, it is in the one entitled “Principles of Philosophy” that René Descartes (1596–1650) presents his detailed discussion on the origin of the Universe, the stars, the planets, and the Earth. In this treatise, specifically in the chapter “On the Earth”, we find the Cartesian thesis concerning the origin of the planet, the formation of its relief, and the dynamics underlying the generation of

³⁶ Randles (1994).

³⁷ Labbé (1646, p. 3 apud Randles, 1994, p. 87).

springs, metals, and minerals—topics that Descartes continued to treat under the domain of Natural Philosophy. It is nevertheless important to note that in earlier writings, such as “The Meteors” and “The World, or Treatise on Light”, Descartes also offers significant reflections on the formation of the Earth, as well as on various natural phenomena acting upon its surface, including winds, rainfall, tides, and others. It is precisely in “The World”—a work composed between 1629 and 1633 but withheld from publication after Galileo’s condemnation by the Church³⁸—that Descartes, for example, ventures an estimate for the age of the Universe: somewhere between five and six thousand years³⁹.

Here, however, our focus will rest exclusively on “Principles of Philosophy”, for, as noted above, it is in this work that Descartes articulates his perspective on the processes that gave rise to the planet and that sustain its present configuration. Moreover, this text is frequently identified as inaugurating the major systematic treatments of the Earth and as having exerted considerable influence on those who would discuss it for the next hundred years⁴⁰. Even so, the works preceding the “Principles” will not be entirely disregarded; they will be brought into the discussion whenever necessary to clarify specific themes addressed by Descartes⁴¹.

Finally, before presenting the Cartesian thesis itself, it is essential to examine Descartes’ physics in greater depth, as well as the philosophical and scientific context in which it was developed. Traditionally, these aspects are either entirely ignored or treated in a highly superficial manner by authors concerned with the history of Geology, rendering the Cartesian proposal virtually incomprehensible. It is within this context that Descartes’ view of the Earth is often dismissed as mere speculation or a simple fable, devoid of any meaningful contribution to the history of Geology, as argued by Oldroyd (1996) and Balan (2011), or even interpreted as a mediocre geological work, as Ellenberger (1988) suggests.

³⁸ Battisti and Donatelli (2009).

³⁹ See Descartes (2015, p. 73).

⁴⁰ Roger (1973), Ellenberger (1988; 1994) and Santos (2024).

⁴¹ This reference to previous works is necessary because, in some passages of the “Principles”, Descartes presents very quick conclusions and, aware of this, directs the reader back to those previous writings for a clearer understanding of the issues under discussion.

The aim here is evidently not to extract modern geological truths from Descartes—although these same authors frequently recall that he was the first to propose an igneous planetary core. Rather, the goal is to situate his ideas within the science of his time, in which he was, without question, an author of exceptional importance. Through the discussion that follows, it will be possible to reassess Descartes' significance for the development of studies on the Earth and his contributions to the emergence of modern Geology.

Cartesian Mechanicism and the Mechanical Philosophy

Philosophy and the History of Science regard Descartes as a central figure in the development and rise of Mechanical Philosophy during the seventeenth century. Emerging from the confrontation between Aristotelianism and the various anti-Aristotelian currents⁴² that flourished during the Renaissance⁴³, Mechanical Philosophy is grounded on a fundamental principle: all natural phenomena—whether on an astronomical or microscopic scale—can be explained on the basis of two key considerations, namely the arrangement of matter and the motion to which it is subjected⁴⁴. Drawing on ancient Greek atomism, mechanistic philosophy adheres to the corpuscular theory of matter; that is, it maintains that matter, conceived as inert and universal, can be divided into an infinity of minute bodies characterized solely by their shape, size, and impenetrability⁴⁵. Motion, in turn, is understood simply as the displacement or degree of agitation of these same corpuscles⁴⁶. Thus, once matter is defined as a set of corpuscles with determinate shape, position, and motion, it becomes possible—through geometry—to measure it, thereby enabling the fusion of the Mathematical Sciences with Natural Philosophy⁴⁷.

In deepening this discussion, Descartes develops a more systematic form of mechanicism⁴⁸. He conceives the Universe as pure extension, that is, devoid of any

⁴² As anti-Aristotelian currents, we can highlight Renaissance Platonism, Hermeticism, chemical philosophies, among others.

⁴³ Menn (1998), Blair (2006), and Garber (2006).

⁴⁴ Nadler (1998).

⁴⁵ Nadler (1998); Garber (2006).

⁴⁶ Nadler (1998); Garber (2006).

⁴⁷ Belhoste (2016).

⁴⁸ Belhoste (2016).

kind of void, and considers natural bodies to be portions of this extension, making them susceptible to geometric measurement⁴⁹. Moreover, the changes of position that a body may undergo in space are geometrically quantifiable, a consideration that allows Descartes to formulate the law of the quantity of motion, defined as a relation between the extension of a given body and its velocity⁵⁰. In this sense, Descartes not only preserves the fusion of Natural Philosophy with the Mathematical Sciences but also establishes a new method of scientific investigation that enables him to describe bodies and their respective motions both geometrically and algebraically - marking the birth of Analytical Geometry⁵¹. It is thanks to Descartes that Algebra becomes integrated into Natural Philosophy⁵².

Accordingly, since all natural phenomena can be explained through matter and motion, and since the relation between them obeys the rigorous and precise rules of the Mathematical Sciences, Descartes sees no distinction between a mathematical rule and a law of nature. Writing to Mersenne, Descartes is categorical in stating that “there is nothing in my physics that is not also in my geometry⁵³.” Thus, the Cartesian physical universe may be interpreted as geometry itself made real, and the laws of nature as that which constitute nature itself⁵⁴.

Although this Cartesian view of the universe was heavily criticized, especially toward the end of the seventeenth century⁵⁵, the idea that Nature operates according to mathematically demonstrable natural laws became the central tenet of mechanistic Natural Philosophy⁵⁶. Furthermore, the view that the Universe is composed of the same matter and governed by the same laws—extending from the smallest corpuscles to the largest celestial bodies—undermined the ancient cosmological division between the Sublunar and Supralunar Worlds, as upheld by Aristotelianism⁵⁷. Mechanicism therefore initiates a process of integration between these

⁴⁹ Belhoste (2016). It is important to note that, for Descartes, large natural bodies have pores, which are filled with corpuscles of matter (Belhoste, 2016).

⁵⁰ Belhoste (2016).

⁵¹ Hall (1964), Rossi (2001); Belhost (2016).

⁵² Hall (1964), Rossi (2001); Belhost (2016).

⁵³ Descartes (*apud* Rossi, 2001, p. 209).

⁵⁴ Rossi (2001); Lenoble (2015).

⁵⁵ For a more in-depth view of these criticisms, see Hall (1963) and Rossi (2001).

⁵⁶ Garber (2006).

⁵⁷ Rossi (2001); Garber (2006).

two formerly distinct realms, revealing the strong tendency toward the uniformization of nature characteristic of seventeenth-century physics⁵⁸.

On the other hand, mechanicism did not limit itself to mathematically demonstrating the natural laws governing all phenomena. It also provided a new model for the functioning of the Universe, fully consistent with its perspective on matter, motion, and, above all, the mode of interaction among natural bodies. To this end, it relied on four fundamental assumptions, as outlined by Rossi (2001, p. 244):

1. nature is not the manifestation of a living principle but a system of matter in motion governed by laws; 2. such laws can be determined with mathematical precision; 3. a very small number of these laws is sufficient to explain the universe; 4. the explanation of natural behavior excludes, in principle, any reference to vital forces or final causes.

Thus, the model proposed for Natural Philosophy to investigate nature—and which would satisfy all these requirements—was the machine. Consequently, mechanicism came to regard natural bodies—living beings, the Earth, the Solar System, and so forth—as genuine machines, differing in no essential way from those operated by artisans⁵⁹. This perspective introduced important considerations regarding the dynamics of nature. First, just as the functioning of a machine depends on the internal motion of its parts, which transmit movement to one another solely through physical contact, all motion in the natural world would be understood in the same way. Hence the extensive seventeenth-century studies on collisions between bodies and the transmission of quantity of motion, as expressed by Descartes himself.

Moreover, conceiving nature as a machine introduced the expectation—or hope—that the natural world might be entirely intelligible⁶⁰. Since the functioning of a machine can be explained simply by identifying its parts and understanding the role each plays in producing motion, it was expected that natural machines would follow the same principle⁶¹. From this, a given natural phenomenon would be explained by Mechanical Philosophy through the construction of a mechanical model

⁵⁸ Garber (2006).

⁵⁹ Rossi (1992); Shapin (1996).

⁶⁰ Rossi (1992); Shapin (1996).

⁶¹ Rossi (2001).

of its functioning, and the more quantifiable and reducible to geometry such a model was, the closer it would be to the truth⁶².

For mechanistic thinkers, the clock was the most fitting metaphor for this new universe, given its structure and the precision of its regular and uniform operation⁶³. Kepler and Boyle, for example, marveled at how the simple oscillation of the pendulum could set all the clock's parts in motion without the need for additional sources of energy for each component⁶⁴. In their view, the universe functioned in precisely this way: a single source of motion transmitted through contact among natural bodies, without recourse to a multitude of agents—such as angels, celestial spheres, or spirits—invoked by Aristotelianism and various anti-Aristotelian philosophies for this task⁶⁵.

Such a perfectly functioning machine could not be the product of mere chance. Just as a fine clock is crafted by a skilled artisan, a machine as perfect as the universe could not have arisen from nothing but must have come directly from the hands of God, now conceived as the great clockmaker or master craftsman⁶⁶. This new conception of God was accompanied by a new understanding of His relationship to creation. If the universe-machine operated with such perfection, the many divine interventions described in Scripture required, at the very least, reinterpretation, prompting renewed discussion on the relationship between revealed text and the natural world⁶⁷.

In the Cartesian version of mechanicism, God assumes a non-interventionist role. For Descartes, God created matter, natural laws, and imparted the initial impulse to matter⁶⁸. From that point onward, all interactions among natural bodies would occur without the need for direct divine intervention, since the universe would be governed by the natural laws already established by Him⁶⁹. Thus, the Cartesian God becomes a guarantor, ensuring only that matter and its laws are preserved over time exactly as they were created⁷⁰.

⁶² Rossi (2001).

⁶³ Rossi (2001); Shapin (1996); Nadler (1998).

⁶⁴ Nadler (1998); Rossi (2001).

⁶⁵ Nadler (1998); Shapin (1996); Rossi (2001).

⁶⁶ Shapin (1996).

⁶⁷ Feldhay (2006).

⁶⁸ Feldhay (2006); Blair (2006).

⁶⁹ Rossi (2001).

⁷⁰ Rossi (2001); Feldhay (2006); Belhoste (2016).

Furthermore, Descartes adopts the process of mathematical deduction derived from Geometry as his methodological model for scientific investigation. Just as Geometry does not derive its most elementary concepts—such as point or line—from experience, but from abstract and logically reasoned definitions, Descartes proposes that science should also ground its fundamental principles in reason rather than in the direct experience of the senses⁷¹. To support this view, Descartes maintains that all human beings possess certain ideas from birth, the so-called innate ideas. Such ideas, he argues, could not have arisen from the mere reflection of the imperfect human mind but must have been placed within it by the Creator⁷². For the natural world, the innate ideas of extension, shape, and motion⁷³ serve as the obligatory starting point for any study of nature, in accordance with the principles of mechanism he defended.

Once the fundamental principles guiding scientific knowledge are established, all subsequent discoveries would result from logical deductions derived from these innate ideas. These deductions would in turn allow further deductions, forming an endless chain of reasoning characterized by extreme clarity and perfect reversibility, since from any point in the chain—or system—it would be possible to return to the origin, the innate ideas, or advance to its most distant consequences. In this sense, the Cartesian natural system is marked by its extreme linearity, much like the algebraic description of complex geometric figures, which can always be reduced to their simplest and most fundamental forms, such as the line, square, or triangle. On this point, Descartes writes:

The long chains of simple and easy reasonings by means of which geometers are accustomed to reach the conclusions of their most difficult demonstrations had led me to imagine that all things, to the knowledge of which man is competent, are mutually connected in the same way and that there is nothing so far removed from us as to be beyond our reach, or so hidden that we cannot discover it, provided only that we abstain from accepting the false for the true and always preserve in our thoughts the order necessary for the deduction of one truth from another⁷⁴.

⁷¹ Hall (1963).

⁷² Cassirer (1994).

⁷³ Cassirer (1994).

⁷⁴ Descartes (apud Hall, 1963, p. 110)

However, such a view of science might suggest that the Cartesian natural system would consist of an infinity of numbers and equations, similar to modern mathematical models used to study natural phenomena. But this is not what we find in his philosophy. The mathematical character of Cartesian thought lies precisely in the axiomatic and deductive nature of his proposal⁷⁵. It is the model—the method employed by the Mathematical Sciences to conduct their investigations—that should be adopted by science, not merely the reduction of natural laws to equations, as Galileo sought in his studies of motion⁷⁶. For Descartes, science is essentially theoretical, and any break in the logical continuity of this structure would necessarily lead to false conclusions⁷⁷. Hence his strong criticism of Natural History and the many reports of scientific experiments found in various memoranda, which he regarded not as sources of certain knowledge about nature but as oceans of confusion and contradiction⁷⁸.

Nevertheless, Descartes was not an enemy of experimentation. As he himself notes, it is impossible to understand the formation of the rainbow without knowing the refraction of light in water⁷⁹. The crucial issue, therefore, concerns how to attain certain, true, and well-founded knowledge of the natural world - something that, in his view, experience alone could not provide, given that our senses constantly deceive us⁸⁰. True knowledge could not be built from the external world but must arise internally, from reason. Hall (1963) thus concludes that, for Descartes, true science is conducted a priori, with experimentation serving only as a later procedure aimed at testing the plausibility of previously established theories.

As we shall see, the Cartesian discussion of the Earth is permeated by this new interpretation of nature and by his methodological proposal for how it should be known. For the first time, the Earth—conceived as the Terraqueous Globe—would be interpreted according to the principles and methods of Mechanical Philosophy. In this process, Descartes, much like Buridan had done for Aristotelianism regarding the emergent lands, becomes responsible for rendering this new object—

⁷⁵ Rossi (2001).

⁷⁶ Hall (1963).

⁷⁷ Hall (1963).

⁷⁸ Hall (1964); Rossi (1992).

⁷⁹ Hall (1963).

⁸⁰ Hall (1963).

born of the Great Navigations and the new Astronomy—intelligible to the emerging modern science.

The Origin and Formation of the Earth and Its Relief

Before presenting Descartes' view on the formation of the planet and its relief, it is important to briefly outline some concepts from his physics, as these constitute the foundation of his entire argument concerning the Earth. Cartesian physics holds that matter can be reduced to three principal properties: unlimited divisibility, figure, and mobility, which are intrinsically interconnected⁸¹. Regarding the first property, it allows matter to assume the most diverse types of figures, which Descartes groups into three main categories, designated as the First, Second, and Third elements⁸². Given the fundamental role they play throughout his discussion on the formation of the Earth, we shall now consider each of them.

The First Element, also referred to as fire, may be defined as the fastest of all material particles, whose movement nothing is capable of impeding. Moreover, these particles are able to penetrate every type of body, and to do so they can acquire as many shapes and sizes as necessary to accomplish this task. Owing to this capacity, they are able to fill any empty space that may exist in the Universe. For Descartes, all stars, including the Sun, are composed solely of matter of the First Element⁸³. As for the particles of the Second Element, called air, they are larger and slower than those of the First Element, yet smaller and faster than those found in the Third. They also possess a spherical shape and permeate the entire Universe⁸⁴.

Finally, the Third Element, or earth element, is characterized by Descartes as the largest and slowest of them all, comprising all remaining matter regardless of its figure. This last category enables him to characterize the various specific forms of matter according to the properties and phenomena observed in particular sub-

⁸¹ Mariconda (2018).

⁸² See Descartes (1997, p. 60). It is important to bear in mind that this categorization does not imply that matter is confined to its respective class; that is, once it belongs to the First element, for example, it would not be prevented from migrating to the Second or Third. Quite the contrary. Nothing prevents one element from becoming another.

⁸³ See Descartes (2015, p. 57).

⁸⁴ See Descartes (2015, p. 57 e 59).

stances. Thus, the matter of water, for example, is described as having a shape similar to flattened cylinders or, in his words, like eels. It is also defined as flexible and slippery, a fact that allows him to explain the various phenomena attributed to it, such as its fluidity and its capacity to change volume when heated or cooled. According to him: “[...] I suppose that the small parts of which water is composed are long, joined, and slippery, like little eels, which, although they intertwine, never hinder or cling to one another, so that they cannot be easily separated [...]”⁸⁵.

Regarding the second characteristic of Cartesian physics, movement, Descartes identifies in it the explanatory basis for the figure and physical states of matter—that is, the solid and liquid states (the latter encompassing both the liquid proper and the gaseous). Thus, the more agitated the particles composing a body are, the greater its fluidity; conversely, the slower they are, the greater the solidity of the matter⁸⁶. Finally, figure would be the result of the collision of the various particles of matter with one another, with their consequent fragmentation produced by movement.

In this sense, figure, matter, and movement are the three essential characteristics for understanding the process of formation of the Universe. For Descartes, it is from the initial impulse given by God to matter—resulting in the collision of the most diverse types of particles—that the three elements mentioned above emerge: fire, air, and earth. Furthermore, in the course of these collisions and fragmentations, the particles adopt a circular trajectory, since Descartes conceives the Universe as full (the “plenum”)⁸⁷. Consequently, the so-called vortex arises: vast regions of matter in continuous circular motion, with a specific direction and orientation, capable of carrying along everything contained within them. Each vortex represents a planetary system, such as the Solar System⁸⁸, and may adopt any direction and orientation in its movement.

⁸⁵ Descartes (2018, p. 244-245).

⁸⁶ See Descartes (2015, p. 36-37).

⁸⁷ The particles adopt a circular motion because, from the very first moment in which they are set in motion, they are also compelled to deviate constantly from their original trajectory due to collisions with others along their path. Such a situation is only possible in a Universe filled with matter; otherwise, the particles would remain indefinitely on their initial course.

⁸⁸ For a more detailed view of matter and the formation of the Universe, see Descartes (1997, p. 60-115).

Thus, in Cartesian cosmology, light and rapid elements would occupy the center of the vortex and form the stars, which constitute the core of its driving force. The planets, in turn, would take positions closer to or farther from this center depending on the amount of matter they contain and, consequently, on their momentum. “This is why we have every reason to think that the Sun and the fixed stars have no other form than that of the entirely pure first element, the heavens⁸⁹ that of the second, and the Earth, together with the planets and comets, that of the third⁹⁰.”

Within this framework, the Earth is interpreted as having been, in its beginning, an incandescent star—the center of a vortex—which lost its light precisely due to the appearance of spots on its surface, similar to those observed on the Sun. According to Descartes, these spots, formed by denser materials of the First Element, were responsible for slowing down the movement of the particles of the First Element, allowing their agglomeration. As a result, the Earth lost its capacity to remain the center of its own vortex and was therefore captured by a stronger one, that of the Sun. It is from this moment that the process of its transformation into a planet begins.

Let us suppose, then, that the Earth we inhabit was once [a star], composed only of the matter of the first element and in no way different from the Sun [...] and fixed at the center of the whirlwind around it. Let us imagine that the less subtle particles of its matter gradually joined together, agglomerating on the surface and giving rise to clouds and other thicker and darker bodies, similar to the spots that continually appear and disappear around the Sun; now, [...] the remaining parts—more voluminous than those of the first two elements—would have the form of the third, then piling up around the Earth and surrounding it on all sides, giving rise to a body almost similar to the air we breathe. Finally, let us imagine that this air became enormous [and thick]⁹¹ and that the dark bodies (which continued to form on the Earth's surface)⁹² could not be as easily destroyed as before, gradually covering and obscuring it. Many layers of such bodies probably piled up on top of each other, and the force of the

⁸⁹ By heavens, Descartes means the entire region between the planets and the stars.

⁹⁰ Descartes (2015, p. 67).

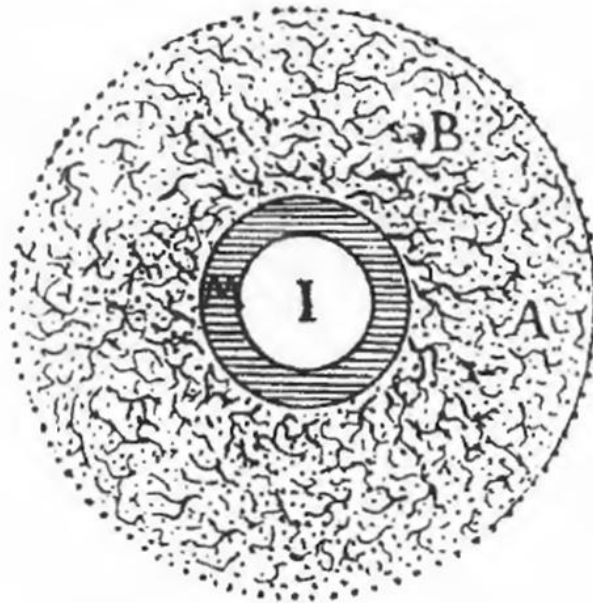
⁹¹ Editor's brackets.

⁹² Apparently, the parentheses are from Descartes' original Latin text. Unfortunately, the editor does not mention anything about them.

whirlwind that contained it diminished so much that it was completely destroyed. Finally, the Earth, together with the air and the dark bodies surrounding it, descended to the vicinity of the Sun, where it currently resides⁹³.

From this point onward, Descartes begins his explanation of the actual formation of the Earth, presenting it as a sequence of deeply interdependent and strictly defined stages, in which the actions of the matters of the First and Second elements serve as the principal agents. Thus, in this initial phase of genuine cooling of the former star Earth, we observe the emergence of three major regions as the result of a true process of decantation, responsible for separating the particles according to the magnitude of their mass, their degree of agitation, and their figure (Figure 8).

Figure 8 - The three regions (I, M, and A) at the time of the Earth's formation. Region B, although indicated, is posterior.



Source: Descartes (1997, p. 176)

⁹³ Descartes (1997, 175-176). It is very interesting to note some Baroque references in this passage. According to Maravall (1997), the biblical story of the fallen angel, decadence, corruption, and obsession with metaphors involving light and shadow are among the favorite themes of Baroque literature. Thus, the fall from paradise experienced by the fallen angel is portrayed as a decline, as it implied the loss of his heavenly light, transforming him into a dark demon, a corruptible and decadent being. A true star that lost its natural light through the darkness that gradually overwhelmed it, just as happened with the Cartesian Earth.

Accordingly, the first region, designated as ‘T’ and which we may regard as the Earth’s core, is composed entirely of matter of the first element, still rotating at great speed: “If we now consider the state that [the Earth] would have presented shortly before descending toward the vicinity of the Sun, we can distinguish in it three very different regions. The first and innermost is marked with I and must contain only the matter of the first element, moving in the same manner as that of the Sun [...]”⁹⁴. The second region, designated as ‘M’, covers the entire surface of core ‘T’, functioning as a kind of envelope. Its formation is directly related to the same phenomenon that gives rise to sunspots and is therefore a hard and opaque layer.

The second or middle region [here marked with M]⁹⁵ is filled with a very opaque [or hard] and solid [or dense] body, so that its pores are no larger than those that do not allow the grooved particles of the matter of the first element to pass through; all the more so because it was formed only with particles of this matter, which are extremely small and did not leave large gaps between themselves when they joined together [...]”⁹⁶.

Although Descartes presents these two regions, he shows little interest in them, arguing that, since no human being has ever reached such depths, it is difficult to offer further commentary. In his view, our true interest should lie in the outermost layer, for it is there that all the objects we see around us are found⁹⁷. Consequently, Descartes directs all his attention to the large region ‘A’ (Figure 8), which, during the planet’s cooling process, undergoes a kind of decantation of the most diverse types of material particles, resulting in the emergence of new areas within this third region, also designated as ‘A’ (Figures 8 and 9).

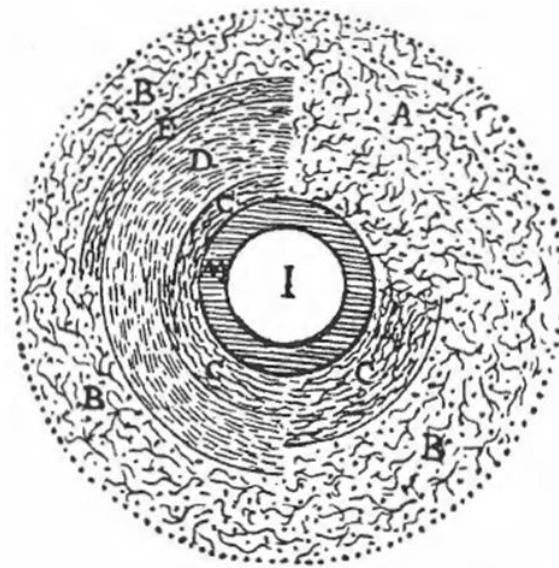
⁹⁴ Descartes (1997, p. 175).

⁹⁵ All brackets are from the editor, except the last.

⁹⁶ Descartes (1997, p. 177).

⁹⁷ Descartes (1997, p. 177).

Figure 1 - Formation of the various terrestrial regions.



Source: Descartes (1997, p. 189).

The process depicted in the image may be compared to a clock: in the first quarter-hour we have layer A; in the second quarter, the emergence of layers B and C from layer A; and so on. The very choice of letters following alphabetical order also indicates the linearity of the proposed model.

These areas of condensed matter organize themselves into concentric layers, whose formation follows a linear and progressive process divided into four acts. Each act, rigidly interconnected with the previous one and itself an absolute condition for the existence of the next—much like the unfolding of an equation—reveals a specific moment in the planet's formation. Beginning with the second act—since the first constitutes the initial condition in which everything is mixed—this stage is characterized by the separation of the particles of the second and third elements found in region A. This process results in the formation of two additional layers: a denser and more opaque one, layer C, and a lighter and more fluid one, layer B: “[...] Thus, the uppermost region of the Earth, having once been as represented in zone A, was later divided into two very different bodies, B and C, in which B is the highest, less dense, liquid, and transparent, and C, by comparison, is very solid, hard, and opaque⁹⁸.”

⁹⁸ Descartes (1997, p. 188-189).

As for the third act of the Cartesian narrative, it is characterized by the emergence of layer D between layers B and C (Figure 9). However, before addressing the characteristics of this layer, Descartes sees the need to discuss in greater detail the matter of the Third Element. According to him, although this matter appears in an infinite variety of forms, it can be classified into three major types. The first comprises particles capable of hooking onto one another and onto other bodies. The second includes all particles of the Third Element that are more solid than those of the first element but whose shape is less prone to interlocking. Finally, the third type consists of those that appear in the finest and most elongated forms, which are incapable of adhering to anything.

[...] although the parts of the third element [...] have a multitude of very irregular and different shapes, [...] they can nevertheless be reduced to three main types: the first comprises all parts that have intricate shapes and whose ends extend in various ways like tree branches or similar things; [...]. The second type contains all those that are endowed with some shape that makes them more massive and solid than the previous ones, without having to be perfectly round or square, as they can have different shapes such as uncut stones [...]. The third is that of those which, being long and thin like reeds or sticks, are neither intricate like the first nor solid like the second, but, like these, blend with bodies B and C; however, as they do not cling, they can be easily pulled out⁹⁹.

In light of the foregoing, layer D is formed through the dynamics of the various types of particles of the third element, which are closely tied to the particular figures they assume. In this process, the concentration of particles of the first and second types occurs through the expulsion of the third type from their interior, since, as Descartes states above, the latter are incapable of adhering to anything. Thus, layer D is composed entirely of matter that is more fluid than that of layer C.

[...] when the parts of the first type, which form body C [...], began to come together, several parts of the third type mixed with each other; however, immediately afterwards, the action of the celestial matter exerted pressure on them and thus these parts of the third type left body C and came together below, in zone D, where they formed a body very different from the two preceding ones, B and C, just as when walking on marshy ground: the only force with which one steps, that of the feet, is sufficient to force the water out of the pores, and thus all the

⁹⁹ Descartes (1997, pp. 189-190).

parts of this water come together in a body that covers its surface. [...] ¹⁰⁰ .

The fourth act is characterized by the emergence of layer E (Figure 9), composed of a type of matter belonging to the third element ¹⁰¹ that is not as dense as that which constitutes layer D, yet possesses greater density when compared to layer B. Moreover, layer E forms a thin film that envelops the entire terrestrial surface, much like the thin and hard shell that covers the surface of an egg ¹⁰² .

As for the parts of the third element that were propelled out of body B [...] they must have remained above the surface. And because many had irregular shapes, like tree branches, they gradually intertwined and attached themselves to each other, forming body E [which is hard and very different from the liquids B and D among which it is found] ¹⁰³ . And although initially this body E did not have a reduced thickness and was like a film or shell covering the surface of body D, it must have gradually become thicker because many particles joined it [both those that descended from body B and those that rose from D] [...]. And because the action of heat and light contributed to raising and lowering these parts of the third element that joined body E, those that were added to them in different regions during the summer or during the day were arranged differently from those that were added to them during the winter or during the night. This is what introduced some distinction between the parts of this body, so that they are now composed of several layers of matter as if they were films spread over each other ¹⁰⁴ .

¹⁰⁰ Descartes (1997, p. 190).

¹⁰¹ Descartes does not go into further detail about the matter of this layer. Apparently, it can be understood as the waste from layers B and D.

¹⁰² The formation of layer E would be similar to the process of milk cream formation. When cooled, the less dense fat floats on its surface. However, because it is denser than the air immediately above it, it is unable to rise, as water vapor does.

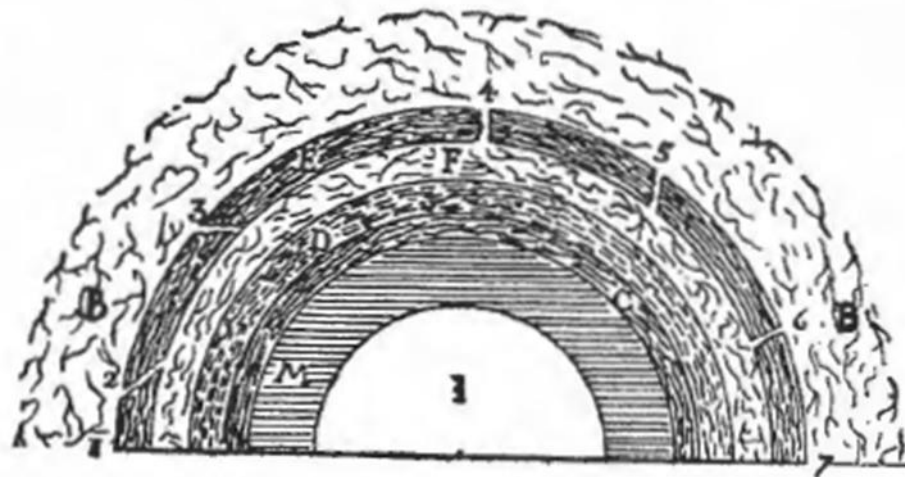
¹⁰³ All brackets are from the editor, except the bracketed ellipsis.

¹⁰⁴ Descartes (1997, p. 192). Here, in a succinct manner, Descartes presents his explanation for the formation of the films, which may be interpreted as sedimentary layers, as we refer to them today. It is important to emphasize that this topic is not mentioned anywhere else in the Cartesian works consulted. Thus, in this brief passage, we can observe that Descartes conceives these sedimentary layers, or films, as enveloping the entire globe—an idea that would remain essentially unchanged for the next hundred years. Moreover, all these layers share the same period of formation; that is, they were produced at the same time as the constitution of layer E. Finally, the differentiation into films observed in layer E is not related to erosional or depositional processes occurring at the surface, but solely to the separation of elements brought about by the dynamics of their particles.

And so, we arrive at the end of the four acts of planetary formation. As a result, we obtain a set of concentric layers that resemble the arrangement of the elements in their natural place as defended by Aristotelianism, organized according to the figure and degree of agitation of their respective particles. In this way, we have the igneous core “T”, which is enveloped by a kind of mantle formed by layers “M” and “C”, the latter being of metallic composition; layer “D”, characterized as a vast internal ocean; the superficial layer “E”, which envelops the entire globe and contains all the preceding layers; and, finally, layer “B”, which may be associated with the atmosphere of this primitive Earth.

However, this image does not correspond to what we actually observe in the present landscape. The Earth’s surface displays a series of irregularities that place it far from the geometric ideal of a perfect sphere represented by layer “E” and illustrated in Figure 9. Aware of this, Descartes initiates a second stage in his work, in which he presents the process responsible for shaping the Earth’s surface—that is, for the emergence of relief as we know it today, with its mountains, caverns, rivers, oceans, and so forth.

Figure 10 - Formation of fissures in layer “E”.



Source: Descartes (1997, p. 193). Emergence of layer “F” and fissures (1, 2, 3, 4, 5, 6, and 7) in layer “E”.

Thus, after the appearance of all these layers, Descartes describes the formation of a final one between “D” and “E”, designating it as “F” (Figure 10). This layer originates from the direct action of sunlight on the particles of matter that compose the liquid layer “D”. According to him, light, by agitating the particles of

layer “D”, imparts the amount of motion necessary for them to move toward layer “E” or even toward layer “B”, through the pores present in layer “E”¹⁰⁵. Once the action of light ceases or diminishes—whether due to the arrival of night or winter—these particles, now in a lesser state of agitation, would find it difficult to return to layer “D”, ultimately accumulating in layer “E”. The result of this incessant dynamic is a reduction in the volume of layer “D”, with the consequent opening of an empty space between layers “D” and “E”. It is precisely this void that gives rise to layer “F”¹⁰⁶.

In fact, during the day and in summer, the light and heat of the Sun would act together on one entire half of body D, increasing the agitation of the particles in this half to such an extent that they could not contain themselves [...]. Thus, being enclosed between the two bodies C and E, several were forced to pass through the pores of body E to rise to B; and then, during winter, they descended again to D due to their weight, since their agitation was less. But many causes could prevent them from returning to body D and cause most of them to join body E [...]. Thus, some managed to pass through body E when they rose and, not finding it descending, remained on the surface, where they served as a sea to increase it. Others were so inserted into its pores that, unable to rise any further, they blocked the passage to those descending. [...]. Thus, many years later, there was much less matter in this body D than when body E began to form [...]. This is also why body E is very thick and dense, since almost all of its particles that left D remained in its pores, thus making it denser [...]. Finally, this caused such a large space to appear between D and E, like F, that it could not be filled with the matter that constitutes body B, some very fine parts of which were able to pass through the pores of body E to take the place of those that left body D¹⁰⁷.

But we must recall that in the Cartesian world there is no empty space, and the existence of a vacuum within layer “F” is absolutely inadmissible. As a result, the space left by the particles of the third element of body “D” is immediately filled by smaller particles of the First and Second elements, which are able to pass through

¹⁰⁵ It should be noted that layer “E” is a jumble of particles of various shapes and, therefore, far from fitting together perfectly.

¹⁰⁶ The system described here by Descartes resembles what occurs in an alembic or distiller.

¹⁰⁷ Descartes (1997, pp. 193-194).

the minute pores of layer “E”. However, Descartes continues, this passage is difficult, which leads to a widening of these pores, resulting in actual fissures in layer “E” (Figure 10).

Thus, although body E was much more massive and heavier than that which lay near F, and probably also heavier than body D, it must nevertheless have remained above for some time, like a vault, owing to its hardness. But when the parts of body D began to form—parts that adhered to its surface—they must have preserved within it many pores through which they could pass, for during the night many of them continually rose toward B by the action of heat, always filling the pores of body E through which they would pass. Yet if, thereafter, some space began to appear between D and E, containing body F, then some particles of F entered certain pores of body E; however, since they were smaller than those of body D, they could not fill them completely. And since there is no void in Nature, and the matter of the first two elements always ends up occupying the spaces left around it by the parts of the third element, this matter of the first two elements rushed into these pores together with the particles of body F, exerting such force to widen some of them that the adjacent ones became very narrow. Thus arose the many fissures in body E, which gradually increased, in the same manner and for the same reasons as commonly occurs in marshy ground when the summer heat dries it¹⁰⁸.

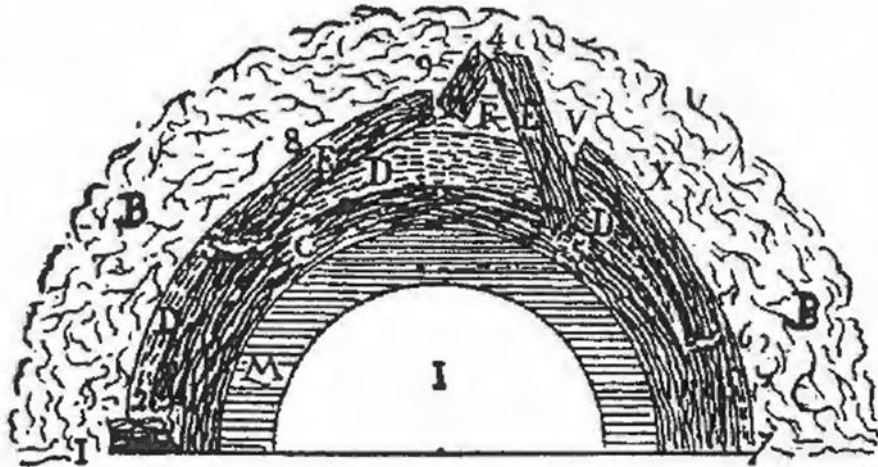
These fissures, growing ever wider, eventually weaken layer “E”, which can no longer support itself and literally collapses onto the liquid layer “D”. Since all the layers are concentric, and layers “C” and “D” therefore have a smaller diameter than that of layer “E”, when the latter collapses it cannot fit perfectly onto either layer “C” or layer “D”, instead becoming wedged upon its own fragments (Figure 11).

Now, as there were many cracks in body E, which gradually increased, they eventually became so large that, unable to maintain the connection between its parts, the dome it formed suddenly broke apart, falling in large pieces onto the surface of body C under the force of its weight. But as this surface was not wide enough to receive all the fragments of this body in the same position as before, some necessarily fell sideways, leaning on each other [...]¹⁰⁹.

¹⁰⁸ Descartes (1997, p. 194).

¹⁰⁹ Descartes (1997, p. 195).

Figure 2 - Collapse of layer "E" onto layers "C" and "D".



Source: Descartes (1997, p. 195).

In the Cartesian thesis, this collapse process is the real cause of the various structures we find on the Earth's surface today, and the way in which each piece of the ancient layer "E" collapsed and positioned itself constitutes a specific geological structure. Thus, mountains would be the fragments that overlapped in the collapse, a kind of rubble from a demolished architectural structure. The plains, in turn, are those pieces that settled in an intermediate position, that is, they did not sink into the waters of layer "D", but they also did not overlap. As for the seas, they appear as a kind of filling between one fragment and another.

Because of all this, if we think that bodies B and F are air, that D is water, and C is a very solid and very heavy inner layer of earth, from which all metals come, and finally that E is another less massive layer of earth, formed by stones, clay, sand, and mud, we can clearly see how the seas were formed above fragments 2, 3, 6, 7, and the like, and that other parts not covered by water and no higher than the rest formed the plains. Those that rose higher and have a greater slope—such as 1, 2, and 9, 4, V—gave rise to the mountains. Finally, considering that these enormous fragments could only have fallen in the manner described if their extremities had broken into many small pieces due to the force of their weight and the impetus of the fall, we can understand why there are cliffs in certain coastal areas—such as at points 1 and 2—and even reefs in the interior, such

as at points 3 and 6; and finally, why in the same region mountains generally have different peaks, some much higher, as in 4, and others lower, as in 9 and V¹¹⁰.

The collapse of layer “E” is largely responsible for shaping the Earth’s surface, constituting the final event in the planet’s formation and the reason why it ultimately assumed the Terraqueous Globe form. Moreover, this collapse may be understood as the logical outcome of a rigidly interconnected sequence of processes, bringing to a close the unidirectional developmental trajectory required for the formation of both the Earth and the Universe itself¹¹¹.

Having completed this major stage in the planet’s formation, Descartes then begins a second phase of his work, in which he examines various physical aspects and phenomena related to the Earth, such as magnetism, the origin of minerals, rivers, and others. Within these considerations—particularly those concerning the Earth’s surface—one feature of the Cartesian landscape deserves special attention for its role in terrestrial dynamics: mountains. Although Descartes did not devote a specific chapter to them, their importance for understanding the Cartesian Earth, traditionally interpreted as existing in a state of equilibrium or steady-state¹¹², is well recognized. This is what we shall examine below.

The great terrestrial distiller: The Mountains

As we have seen, mountains appear to Descartes as the simple result of a collapse. More than that, they constitute the logical outcome of the superposition of two bodies with different diameters. Descartes represents part of these structures in the form of a pyramid, as can be observed in Figure 11. Such a structure is nothing more than the mountain itself, whose hollow interior is to be filled with another type of material.

¹¹⁰ Descartes (1997, p. 195-196).

¹¹¹ Roger (1973). Roger (1973) also points out that, given the role of natural laws in Cartesian Natural Philosophy, which, as we have seen, are closely related to Geometry, it is impossible for the Earth and the Universe to follow any other path to their formation. Thus, no matter how many times they could be restarted, they would always go through the same events and arrive at the same result.

¹¹² Ellenberger (1988) and Gohau (1990).

Thus, the interior of the mountain is composed of a portion of layer “C” (metallic) at its base, followed by the liquid layer “D” (water), and finally by layer “B” (water vapor and other volatile materials). If we consider that all of this is contained within a pyramidal structure, it is not difficult to envision the mountain as a vast distillation apparatus¹¹³, merely awaiting a source of heat to begin operating. And Descartes identifies this source: light. Given that the incandescent core of the Earth is encapsulated by the solid layer “M”, sunlight is identified by Descartes not only as responsible for heating the Earth’s surface, but also for warming its deeper layers.

It should also be noted that the terrestrial parts thus agitated by sunlight agitate others beneath them, and these agitate others further below, and so on. Thus, even though the sun's rays do not go beyond the first surface of terrestrial bodies, which are opaque and dark, there is always half of the Earth heated by the Sun, and so its heat reaches at the same time the lower zones of the third element that form the second¹¹⁴ or middle region¹¹⁵.

With this structure established, and taking the mountain as the central point of analysis, Descartes begins his explanation of several important phenomena, among which we may highlight the dynamics of surface water (the formation of rivers, springs, and the accumulation of seawater) and the origin of metals and minerals. Beginning with the first, Descartes shows that the agitation, or heat, produced by sunlight, upon reaching the innermost layers of the mountain, sets the water present in layer “D” into motion, allowing the particles that constitute it to gain movement and rise toward the summit—that is, to evaporate. Once there, they penetrate the pores of the mountain’s walls and, upon losing momentum through collisions with other particles, are unable to return by the same path, for they begin to bend and entangle with one another. In other words, the water condenses. Now once again in liquid form, this water flows down the mountain, giving rise to springs which, in turn, generate and feed the rivers that make their way toward the sea.

But [without further ado]¹¹⁶ let us begin to examine the outer earth, which [as we have already said] is divided into many frag-

¹¹³ Ellenberger (1988).

¹¹⁴ Region between layers “C”, “D”, and “E”.

¹¹⁵ Descartes (1997, p. 188).

¹¹⁶ All brackets are from the editor, except the bracketed ellipsis.

ments, the deepest ones being covered with sea water; the highest ones form the mountains; and those situated between them give rise to the plains. Let us look at the causes that give rise to springs and rivers whose water never runs dry, even though their waters no longer flow into the sea; in fact, all this fresh water that flows into the sea does not increase it or make it less salty. Therefore, it is necessary to consider that there are large concavities filled with water under the mountains and fields, from which heat continuously causes many vapors to rise, which, being nothing more than particles of water separated from each other and very agitated, flow through all the poles of the outer earth and thus reach the highest surfaces of the plains and mountains. [...]. When these vapors reach the high parts of the mountains, they can no longer rise, as their agitation decreases, and so all the particles come together and resume the form of water, unable to descend through the pores through which they rose, because they are narrow, but finding other passages a little wider in the various crusts [or layers that, as already mentioned, make up the Earth] through which they pass through cracks that [as I have also stated] are found in this outer earth. When they fill them, they form springs that remain hidden underground until they find openings on the surface through which they emerge, giving rise to springs whose waters, running through sloping valleys, join together in rivers and finally reach the sea¹¹⁷.

One of the immediate consequences of this structure in operation would be a rise in sea level, followed by the depletion of the pools of layer “D” within the mountains—an outcome that would ultimately eliminate springs and rivers. Descartes, however, does not envision such a catastrophic scenario for the world, for in light of the debris of layer “E”, it is entirely plausible to imagine the existence of passages through which seawater could once again make its way into the interior of the mountain.

Now, although a great deal of water continually flows out of the [concavities located under the]¹¹⁸ mountains [to which it rose], the water flows into the rivers and into the sea, and yet these concavities are never depleted, and the sea does not become any larger. This is due to the fact that the outer earth was formed by the process I have already described: with the remains of body E, whose fragments fell unevenly on the surface of body C, leaving many wide passages under these fragments through which as much seawater enters under the mountains as flows out

¹¹⁷ Descartes (1997, pp. 204-205).

¹¹⁸ All brackets are from the editor.

above them towards the sea. Thus, the flow of water in this land mimics that of blood in the bodies of animals, where it circulates, flowing rapidly from the veins to the arteries and from the arteries to the veins¹¹⁹.

In this way, we obtain an uninterrupted circuit in which seawater penetrates the depths of the Earth until it reaches the interior pools of the mountains, where—indirectly heated by sunlight—it undergoes evaporation. These vapors rise to the summit, condense, and flow down the slopes of the mountains, forming springs and rivers which, in turn, reach the sea and restart the entire process¹²⁰. In doing so, Descartes not only accounts for the formation of surface watercourses but also ensures a perpetual state of equilibrium at sea level.

As for metals and minerals, both possess a similar process of formation, for they arise within the interior of the mountain under the effect of heat produced indirectly by the action of light. Metals, understood as a mixture of various particles of the third element, emerge on the walls of mines through a multistage process. First, corrosive particles identified by Descartes as salt, upon leaving layer “C”, detach certain other particles from that layer. At this point, all of this is already within the large pool of layer “D” inside the mountain. There, these particles mix with others characterized as oily—or sulfurous, in Cartesian terms—making it easier for them to be carried by particles of quicksilver, or mercury, when heated. In this process, the quicksilver transports the metals to the walls of layer “E”, depositing them in its pores and causing them to emerge in the mines like a kind of subterranean perspiration.

¹¹⁹ Descartes (1997, p. 205).

¹²⁰ The question of why seawater salinity is not present in fresh water is easily explained by Descartes himself, given this cycle. According to his physics, salt particles differ from those of water because they are larger and more rigid. Thus, when they are forced to cross layer E, their path is blocked by the pores of this layer, which act as a filter, retaining the salt in the large layer D. This would explain why, while the waters of springs and rivers are fresh, those of the sea remain salty. For more details, see Descartes (1997, p. 206) and the discussion on salt in Descartes (2018, pp. 257–268). It is worth mentioning that Descartes comments on the existence of saltwater springs, which are explained by the occurrence of deep cracks that reach seawater or by some accumulation of salt particles due to water evaporation (Descartes, 1997, p. 206). However, these sources appear as special cases and do not compromise the general water cycle proposed by him.

I have already explained [...] the three types of bodies that seem to me to be most closely related to what chemists usually consider their three principles, which they call salt, sulfur, and mercury. In fact, we can take these corrosive materials for their salt, these small branches that form an oily substance for their sulfur, and quicksilver for their mercury. I believe that the real reason metals appear in mines is because these corrosive substances come out of the pores of body C and cause some of its particles to separate from the rest; and these, being enveloped and as it were coated with branches of oily matter, are easily pulled from C to E by the particles of quicksilver when agitated and rarefied by heat. Thus, according to the different sizes and shapes that these particles acquire from body C, they form various species of metals. And I would have explained here what this consists of in particular if it had been possible to carry out all the experiments required to verify my reasoning on this subject¹²¹.

And yet,

Thus, the vapors of fine silver that rise through the small cracks and wider pores of the earth's interior carry with them particles of gold, silver, lead, or any other metal, which then settle there [...]. But sometimes it remains there when it encounters many exhalations whose very fine particles envelop their own, thus transforming them into cinnabar. Finally, it is not only quicksilver that can carry metals from the earth to the outside, but something also similar happening to others such as copper, iron, and antimony¹²².

This process is somewhat obscure, and Descartes himself acknowledges the need for a more satisfactory explanation of the phenomenon. Yet the most important point here is his demonstration that the emergence of metals is nothing more than a simple physical process, analogous to distillation, occurring within the interior of the mountain. Moreover—and perhaps this is the most significant aspect—the process is uninterrupted, constituting a circuit analogous to the circuit of water. In other words, metals are in continuous formation inside the mountains. As for minerals, they participate in this same dynamic, arising from a broad mixture of vapors, volatile substances, and exhalations¹²³ originating from the great interior

¹²¹ Descartes (1997, p. 204). At the end of this excerpt, we find an example of the Cartesian perspective on experience, as stated by Hall (1963).

¹²² Descartes (1997, p. 208).

¹²³ Vapors, volatiles, and exhalations are distinguished by Descartes according to the relationship between the form assumed by a given matter of the third element and the ease with which that form is capable of receiving a certain quantity of motion. Thus, for

reservoir and condensed upon the walls of the fragments of layer “E”—that is, within the body of the mountain.

In addition to the vapors that rise from the waters beneath the outer earth E, the inner earth also releases large quantities of penetrating and corrosive volatiles and many greasy and oily exhalations, and even quicksilver, which, rising in the form of vapor, carries with it parts of other metals; as all these things mix, they give rise to various minerals¹²⁴ [...].

Conclusion

In light of what has been discussed, we can ascertain the importance of the Terraqueous Globe for the structuring of Descartes's proposal concerning the Earth. In this sense, while Descartes took this new conception of the planet as the starting point for the construction of his thesis, he also promoted its incorporation into Natural Philosophy. By interpreting the Terrestrial Globe as a machine, breaking it down into parts, and translating it into mechanistic language, Descartes can be seen as responsible for rendering this new object—emerging from the Great Navigations—intelligible to the rising new science and, for that very reason, a new scientific object. An object that Descartes distinguishes from the Sublunar World not only through the implosion of the natural place of the elements and the rejection of the eccentricity of the sphere of earth, but also by giving it a beginning and a past structured according to physical, geometrical, and logical principles.

From this perspective, Descartes completely breaks with the Aristotelian view of the world's eternity, which had dominated Natural Philosophy until then. In the Cartesian proposal, the Earth has a clearly demarcated beginning, and this beginning of time and the unfolding of its past—understood as absolutely linear—can only be accessed and comprehended by reason. Not even the Mosaic chronology of the world's creation, as presented in the biblical book of Genesis, is considered by Descartes a valid source of information for this moment.

example, vapors consist of those smaller particles that are easily agitated and that, precisely for this reason, acquire great speed. The water particle is a case of this type. For further details, see Descartes (2018, pp. 250–268).

¹²⁴ Descartes (1997, p. 207).

Thus, in the long process of constructing a history for the Earth, we see that the Cartesian proposal rendered the planet's past susceptible to scientific investigation. Of course, we may raise a series of questions regarding the nature of this past and the means by which it may be accessed, for, in sum, Cartesian methods differ greatly from those of modern Geology. Nevertheless, it is precisely from his proposal that an entirely new universe of discussions emerges concerning how the beginning and the unfolding of the planet's past should be conceived, as well as how such matters ought to be debated—topics that would endure throughout the following centuries.

But if, for Descartes, the Earth had a beginning that unfolds according to a rigorously determined sequence, on the other hand, it will have no end. At no point in his theory does he present even the slightest possibility that the Earth might return to its initial conditions or undergo any moment of total destruction of its structures. In consequence, through his circuits, another temporal conception comes into play, one much closer to a cyclical perspective of time. Once the structural formation of the planet is completed, terrestrial surface phenomena would present themselves in repetitive fashion. From the origin of rivers to the formation of metals, there is no indication of the possibility of alteration or interruption in the functioning of these cycles within the great terrestrial machine. In a certain sense, the fact that Descartes describes the formation of rivers, metals, and minerals using the present tense is not merely a stylistic choice; it reflects the idea that they are in perpetual formation and destruction, thereby conveying the perspective of a world in absolute dynamic equilibrium, or in a steady-state condition, as also defended by Aristotle and Buridan. Even the catastrophe of the collapse of the layers—something in itself a moment of disorder and rupture—is logically deduced, with its consequences quickly absorbed by the dynamics of the Cartesian circuits once set into operation.

It is also important to emphasize that there is no indication in these circuits, nor in the rest of his physics, that our planet follows any kind of developmental trajectory or is destined to fulfill some predetermined end. The Earth would thus be left only to witness the eternal repetition of its circuits which, combined with the refusal to ascribe any destiny to it, allow us to conceive that the planet, from a Cartesian perspective, would also be eternal once its stabilization had been achieved. In a certain sense, Descartes ends up promoting a subtle concordance

between the Christian perspective of a beginning of the world and the ancient view of the eternity and dynamic equilibrium of the terrestrial surface.

Finally, it is worth noting that Descartes's thesis on the Earth is far from being a mere anecdote of its time, with only his idea of the planet's incandescent core remaining as something to be remembered, as the history of Geology often portrays it. In reality, his theory would directly and indirectly shape discussions on the planet's relief for the next hundred years after the publication of the "Principles of Philosophy". It is considering this that, for example, Magruder (2000) asks whether the theories of the Earth that emerged in the late seventeenth century are not, in fact, all derived from Descartes. Indeed, not only was the idea of a beginning for the Earth incorporated as a scientific truth of the period, but also his ideas concerning the concentricity of the planet's original layers, the formation of mountains through the collapse of those same layers, and the permanence of its circuits would appear in most of the major theses that sought to discuss the Earth and its past—most notably in the aforementioned theories of the Earth developed by English millenarians such as Thomas Burnet (1635–1715), John Woodward (1665–1728), John Ray (1627–1705), and William Whiston (1667–1752).

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