Desmarest's "Determination of some epochs of nature through volcanic products" (1775/1779)

*In 1775, Nicolas Desmarest (1725–1815) presented an interpretation of geological evidence he had been examining for over a decade, among the extinct volcanoes of Auvergne in south-central France. He interpreted the volcanic remnants in that region in terms of **three successive epochs, distinguished from one another by their degree of erosive alteration and the different topographic positions they held following extensive denudation.** He insisted on the utility, for the establishment of sequential stages in the region's history, of what he called his '**analytical method**' of working **backward in time**, from recognition of the most recent and therefore least altered products, to reconstruct in the imagination those more thoroughly disturbed and confusing remnants of earlier periods. In addition to being a landmark effort in historical geology based on local observation, Desmarest's paper was also notable as an expression of what would come later to be called uniformitarian thinking: he argued that the **erosive processes responsible for wearing down the lavas must have operated gradually and constantly.** While Desmarest seems never to have wavered in his view of volcanic action as a subordinate agent in the overall dynamics and history of the globe, he showed awareness that his analysis of the Auvergne lavas pointed toward a considerable role for volcanism during long portions of the province's geological history.*

*The nearest thing to a contemporary publication of Desmarest's 1775 presentation came more than three years later, in the form of an 'excerpt' in the February 1779 issue of the journal *Observations sur la physique*. An English translation of that excerpt is presented in the present paper for the first time.*

Introduction

Historical discussion of Desmarest's paper

On Wednesday, 15 November 1775, the Académie Royale des Sciences of Paris held its regular autumn public assembly in its quarters

within the Palais du Louvre. On this occasion, five speakers—all of them holders of junior ranks within the Academy—had been chosen to showcase their latest work. The first in order of presentation was Nicolas Desmarest, and the paper he read may be seen in retrospect as a landmark in the marshalling and interpretation of geological evidence in *historical terms*. It resulted from the investigations that Desmarest had begun, a dozen years earlier, of the extinct volcanoes of Auvergne. It set forth a general analysis of the region's volcanic phenomena in terms of *three distinct epochs* of their production, with observations on the geological significance of that analysis.¹

The Champagne-born Desmarest had made his first visit to Auvergne in 1763, fulfilling his official duties as an examiner of industrial practices for the royal Bureau of Commerce. (In any assessment of Desmarest's long and active scientific career, one must take into account that through much of it he held employment as an inspector of manufactures. Besides providing him with the foundation of a livelihood and associations with reform-minded figures in government, this also gave him ample opportunities to make observations in natural history.) The existence of extinct volcanoes near the city of Clermont had been recognized in 1751 by the botanist-mineralogist Jean-Étienne Guettard (1715–1786), travelling in the company of his friend and colleague, the lawyer Chrétien-Guillaume de Lamoignon de Malesherbes (1721–1794). Following Guettard's formal report (1752) to the Academy on this discovery, Desmarest was the first naturalist to make a major effort to enlarge upon this new knowledge and by the end of the century, Auvergne was coming to be known as a place of special value for geologists (Taylor, 2007).

Desmarest's attention was quickly drawn to the abundant examples of columnar basalt in the Auvergne lava flows, which were traceable in many cases right up to the craters from which they had issued. In 1765, Desmarest—not yet an Academy member—was permitted to present before it an extensive account of his determination that the presence of basalt prisms was a reliable indicator of past volcanic action. An abbreviated version of his report appeared in 1768, as an explanatory accompaniment to two illustrations of prismatic basalt among the natural-history plates for the highly influential *Encyclopédie* of Diderot and d'Alembert. That pair of drawings had been made by an artist (Jean-Jacques de Boissieu, 1736–1810) attached to a cartographic project, begun in 1764, to chart a portion of Auvergne's volcanic district. This was a mapping project for which Desmarest had succeeded in gaining government sponsorship. In collaboration with Desmarest, the royal cartographic engineer François Pasumot (1733–1804), along with an assistant, Dailley (forename and dates unknown), produced a remarkable map that was published in the *Mémoires* of the Academy of Sciences in 1774. The map accompanied Desmarest's lengthy study of basalt presented before

¹ The five speakers and their subjects were reported in *Mercure de France*, December 1775, pp. 140–141. The Paris Academy traditionally resumed its annual schedule, following a two-month vacation, with the autumn *assemblée publique*—often called the *rentrée de la Saint-Martin*—on the meeting day following Saint Martin's Day (11 November). The other annual public *séance* occurred in the spring, just after Easter. Except for these two public sessions, the Academy's regular meetings—held on Wednesdays and Saturdays—were generally closed to outsiders, although from time to time specially invited guests were admitted.

the Academy in 1771, a few months after his appointment to membership of that body.²

Desmarest's 1775 paper appears not to have created any major public stir. In fact, it was not even included within the selection of research reports published in the Academy's *Mémoires* for that year.³ Possibly the motivation underlying belated publication of an 'excerpt' of Desmarest's paper, in the February 1779 issue of *Observations sur la physique*, had to do with contention over priority. Just at that time a public claim was being made by Georges-Louis Leclerc, the Comte de Buffon (1707–1788), to effective proprietorship of the notion of 'Epochs of Nature': the title of the latest, much celebrated, treatise within Buffon's famous series of volumes, *Histoire naturelle*.

Buffon's *Des époques de la nature*, with an official imprint of 1778, was publicized extensively starting late that year, although it only went on sale in April 1779. Its patrician author held positions of high scientific prestige—he was superintendent of the Royal Garden and the King's natural history collections, and was treasurer of the Academy of Sciences—and he had an enviable reputation as a writer. If Desmarest envisioned a contest with Buffon over ownership of the expression 'epochs of nature', that humbly-born and comparatively obscure savant was at a serious disadvantage. In any case, the late Jacques Roger, who was the leading Buffon scholar in our times, and who suspected a rivalry between Desmarest and Buffon over the term *époques*, has documented prior geology-related use of the expression by other writers dating back to the 1750s, including at least one—Nicolas-Antoine Boulanger (1722–1759)—whose work was manifestly a resource from which both Buffon and Desmarest had drawn.⁴

Buffon's *Époques de la nature* was a work of a much grander sort than Desmarest's cautiously local, field-based study. Addressed

to a broader and less specialized public than the readership of the still rather new journal *Observations sur la physique*, Buffon's book amounted to a comprehensive vision of the Earth's origins, development, and future prospects as a habitat for living beings. It belonged squarely within the tradition of 'Theories of the Earth', and was meant to be read as both science and literature. It represented an interest in fitting known facts into an admittedly conjectural system, emphasizing a sequence of stages in the Earth's progressive transformation. It even ventured to assign specific periods of time to those stages, and to fix the Earth's age in years.

By contrast, Desmarest's interpretation of his Auvergne investigations reflected a spirit of empiricism and caution in theorizing, seeking to use observed facts as a foundation for inferring only a limited portion of a sequence of past events within a circumscribed locality. Desmarest did not pretend to estimate the length of his epochs in years—he did not even assert that they were continuous, leaving open the possibility that there might be 'gaps' between them. Even though Desmarest clearly believed such local and incomplete analysis held out promise for eventual development of broader understanding of the globe's general history, his manner suggested it could be of no immediate use to determine the age of the Earth as a whole. In the decades to come, the investigatory spirit of disciplined reasoning from observations exemplified by Desmarest would constitute a model for adapting specific geological information to a historical framework, for members of the small but growing fraternity of specialists in the emerging science of geology. At the time, however, it gained only a minor fraction of the attention commanded by Buffon's grand synthesis, which, it must nonetheless be acknowledged, did play an important role in orienting geological thinking at large toward a developmental way of conceiving the Earth.⁵

Prior to 1775, Desmarest's reports on his Auvergne researches

² The original text of Desmarest's 1765 presentation to the Academy—referred to in its *procès-verbaux* as a 'Mémoire on Basalt or Egyptian Stone'—has not been found. That it was an extensive report, covering much of the same ground later addressed in Desmarest's 1771 presentation, may be judged by the thorough evaluative report given to the Academy a year later by Mathieu Tillet (1714–1791), Bernard de Jussieu (1699–1777), and Louis-Jean-Marie Daubenton (1716–1800). In fact, in the *plumitif* (draft minutes) by Jean-Paul Grandjean de Fouchy (1707–1788) for the meeting of 11 May 1771 it is recorded that the memoir that Desmarest read that day as an Academy member was the same as that which he had presented as an *étranger* in 1765. In 1765–1766 Desmarest travelled extensively in Italy, as a companion to the young Duc Louis-Alexandre de La Rochefoucauld d'Enville (1743–1792). During this tour he gave close attention to the volcanic phenomena of northern and central Italy, including the Naples region, and compared what he saw there with the volcanic productions he had seen in Auvergne (Taylor 1995). On Desmarest's cartographic collaboration with Pasumot see Taylor (1994); a facsimile of the resulting map is presented in Taylor (2007).

³ In fact, Desmarest was the only one of the five speakers, from that mid-November public assembly, whose paper was *not* represented in some significant manner in the *Histoire et mémoires* volume of 1775. Two of the papers were printed in that year's *Mémoires*—one by Jean-Rodolphe Perronet (1708–1794), a practical hydrological project for the Paris water supply, the other by Mathurin Brisson (1723–1806) and Louis Cadet de Gassicourt (1731–1799), an inquiry into the chemical effects of electricity on metallic calces. The two others were the subjects of extensive discussion in the *Histoire*, and soon appeared in separate contemporary publications—books by their respective authors: the astronomer Jean-Sylvain Bailly (1736–1793), a history of ancient astronomy; and the astronomer Achille-Pierre Dionis du Séjour (1734–1794), on Saturn's rings.

⁴ The prominent historian of geoscience Martin Rudwick has suggested (2005, pp. 207–208) the possibility that Buffon might have used his authority in the Academy to block inclusion of Desmarest's memoir in the Academy's *Mémoires*. It is interesting that one academician in attendance at the 1775 *rentrée*—the young chemist Antoine-Laurent Lavoisier (1743–1794)—appears to have found Desmarest's presentation far the most interesting of the five papers: Lavoisier's surviving notes from that public occasion reflect his attentiveness with a page-long digest of what Desmarest had to say, whereas he gave Bailly's paper just a few lines and for the three others' papers only the titles were noted (Archives, Academy of Sciences, Lavoisier *plumitif*). The contents of Lavoisier's notes, incidentally, suggest that Desmarest's 1779 publication in *Observations sur la physique* included all the main points made in his 1775 presentation; we are thus left with an impression that the published article, identified as an 'excerpt', might not have been a very seriously abridged version of the paper as presented at the Academy's public meeting.

⁵ Without retreating from the position that Desmarest's project of constructing geological knowledge upon field-based data differed greatly from Buffon's habit of trying to fit observations into a rationally-derived scheme, I maintain that the place of contemporary Theories of the Earth in Desmarest's overall geological outlook was not entirely negative. I have tried to show (Taylor 1992, 2008) that elements of the traditions of Theories of the Earth, particularly as practised by Buffon, had a constructive role in the way Desmarest approached geological problems. Contemporary dissemination of Desmarest's 1779 *Observations sur la physique* article may have been broadened a little by production of an offprint—a common enough practice at the time—the title of which began with 'Précis' rather than 'Extrait'. Desmarest presented this research again, in more extended form, in 1804 for the *Institut de France* (with four maps, volume published 1806). Later still, in his huge compilation of materials for the multi-volume *Géographie physique*, in the *Encyclopédie méthodique* series, Desmarest reproduced the entire 1779 version, within the article 'Époques de la Nature': vol. 4 (1811), pp. 43–49.

Figure 1. A map (one of four) from Desmarest's 1806 publication, '*Mémoire sur la détermination de trois époques de la nature par les produits des volcans*'. (His 1779 article had no maps or figures of any kind—not at all an unusual fact for geoscience publications of that time.) The map reproduced here was one of two plates displaying the volcanic remnants from the most recent of the three epochs described in his study. For this 1806 publication, Desmarest altered the reverse-chronological way of counting epochs he had chosen in the 1770s, adopting the convention of counting in chronological order. The map features the volcanic flows (stippled) emanating from two main centres of eruption. The most prominent one emerges from the north flank of the Puy de Pariou (centre-left), and runs generally eastward toward the city of Clermont. This flow at first spreads over the plateau northeast of the Puy de Dôme (located in the southwest, just above the map legend), before dividing to progress down two gorges that had been eroded into the plateau's eastern margins. The second conspicuous recent centre of eruption is the Puy de Gravenoire (lower-centre), with flows going in two directions, northward and eastward. A flow issuing from a third centre of eruption of the latest epoch, in the upper left corner of the map, runs out of view to the northeast, but reappears in the map farther eastward, terminating at St. Vincent.

Desmarest explained that the geologically young age of these flows was attested by their cover of scoria and porous lavas, in 'bizarre forms'. At certain points, he said, streams running adjacent to these modern flows have excavated beds well below the bottoms of the flows, testifying to significant physiographic changes effected in the time since the flows were emplaced. Desmarest noted the presence of springs at the terminus of each recent flow. In Desmarest's discussion of this map (1806, pp.279–282), he pointed to an area near its centre, between the two lower branches of the Pariou flow—especially between the denuded second-epoch crater-remnant or culot near La Baraque and the eroded plateau extremity at La Prudelle—as a locality where one can see clearly delineated the differences between the relatively fresh volcanic flows of the most recent (third) period of eruption and the extensively-denuded lava productions of the second epoch.

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had concentrated on basalt's identity as a volcanic production. In his new paper he shifted focus from basalt and its volcanic origins, to discuss how his examination of the Auvergne lava remnants yielded analysis into distinct epochal phases. (He also emphasized, however, that recognition of multiple stages of volcanism in Auvergne was important for understanding the volcanic character of lavas whose sources had been obliterated by erosion.) He had mentioned the idea

of such sequential analysis before, as well as the massive extent of denudation involved in a proper understanding of the Auvergne terrain.⁶ But this was the first time he had brought the proposal in from the wings, as it were, to centre stage.

The notion of treating natural phenomena in terms of temporal sequences was not an obvious or usual thing for most naturalists of this time, and Desmarest's basic orientation toward geographical

understanding was not out of the ordinary in this respect. Indeed, he had written a lengthy, methodology-oriented article on Physical Geography (1757) for Diderot and d'Alembert's *Encyclopédie*, in which he supported a concept of developing knowledge of the Earth by reasoning from specific observations to general recognition of law-like regularities in spatial configurations. Desmarest's early convictions on how to formulate scientific knowledge tended to be guided by his respect for natural philosophy and its emphasis on explanation through general laws. On the other hand, his intellectual preparation for a career in science had included strong associations with antiquarian scholars, which must have given him some acquaintance of the investigatory methods and explanatory predispositions of the historians of his day (Taylor, 2001a). His adoption of the term *époque* for discussion of natural phenomena may well have resulted from his familiarity with the chronologers' lexicon.⁷

Desmarest's selection as a speaker for the Academy's *rentrée* in 1775 was an opportunity to highlight his intellectual originality—a quality he needed to confirm periodically in order to fulfill expectations weighing on all working members of the Academy, and to gain advancement therein. At fifty years of age by then, Desmarest was hardly young. But he was still a relatively fresh academic appointee, having been named to the Academy less than five years earlier. In common with all but one of his fellow presenters, at that November public *séance*, he held the middling rank of *associé* (Brisson's [see Note 3] status was that of *adjoint* or assistant, the most junior of the three ranks). Because chances for promotion to the full rank of *pensionnaire* depended on vacancies brought about, usually, by death of one of the incumbents—or, more rarely, by a retirement—there was no telling when the next opportunity for such coveted advancement might occur. Desmarest could not know then, of course, that his promotion to a *pensionnaire*'s chair would come about seven years later, towards the end of 1782, when he would succeed Jacques de Vaucanson (1709–1782) within his own section of *mécanique*. But he surely knew that any such ambition was in

vain without further demonstration of the scientific promise and technical acumen that had warranted his election in 1771.⁸

What Desmarest read, then, to the public assembly in November 1775 was intended as additional proof, beyond the achievements for which he was already recognized, of his merits as a perceptive observer and an original interpreter of nature. What was most innovative and striking about this paper was the construction, out of local geological observations, of a set of distinct epochs or periods represented by those data. Almost as remarkable were his assertions to the effect that extensive changes in the Auvergne landforms had resulted from ordinary erosive processes, operating at more or less constant rates over great lengths of time.⁹

A practice of ascertaining the order of rock assemblages based on local observation had a long string of precedents by 1775. This was particularly true for the corps of mining specialists, for whom such knowledge had great practical value. Similar ideas had surfaced also, however, in the work of philosophical-minded authors such as Nicolaus Steno (1638–1686) or Robert Hooke (1635–1703) in the previous century. On the mining side, during the eighteenth century the process of rationally formalizing practical knowledge of the 'subterranean geometry' of rock masses—that is, their spatial relations—became the central objective of the new science of *Geognosie*.

By the mid eighteenth century a convention had emerged—based on ideas put forward by writers like Antonio-Lazzaro Moro (1687–1764), Johann Gottlob Lehmann (1719–1767), Giovanni Arduino (1714–1795), and Guillaume-François Rouelle (1703–1770)—affirming a fundamental generic and structural distinction between 'primitive' or 'primary' rocks on one hand, and overlying 'secondary' or stratified rocks on the other. Efforts to put the series of secondary layers in more detailed order based on locally-focused studies intensified in the 1750s and 1760s, as exemplified by Lehmann, Arduino, and Georg Christian Fuchsel (1722–1773). Even in these cases, however, the emphasis appears always to have been *more structural than chronological*—aimed first at establishing knowledge

⁶ E.g., Desmarest (1774, pp. 736–739, 755, 768–775, and map); Desmarest (1777, pp. 645, 654). These two publications represented the paper that Desmarest delivered at the Academy on 11 May 1771. During this period the publication dates of the Academy's annual collections of research papers were in arrears by anywhere from two to four years. This being the case, it sometimes happened that authors took advantage of the passage of time to insert additional information or ideas, which might have come to them after the time of the original presentation.

⁷ Buffon and Desmarest were both engaged, in these efforts, in establishing a new meaning for the word 'epoch'. In traditional usage (for chronology, but also in more general speech) the word referred to a special moment in time—a decisive marker or milestone in the time continuum. As an 'epoch' now came to be understood as a distinct period, the term's original meaning as a 'decisive moment' or key point in time gradually moved toward obsolescence. (See Rudwick, 2005, pp. 143ff., and Taylor, 2001b.)

⁸ At this time, the Academy's structure recognized no such thing as a specialization in 'geology', or even in the well-established science of mineralogy. For experts in natural history the most obvious academic identifications were the classes of botany, where Guettard, Henri-Louis Duhamel du Monceau (1700–1782), and Bernard de Jussieu held the *pensionnaire* posts; or of anatomy, in which Daubenton, Jacques Tenon (1724–1816), and Jean-François-Clément Morand (1726–1784) were then *pensionnaires*. Desmarest's qualifications were in certain respects quite well fitted, however, to the Academy's class of *mécanique*. A man of science with a solid foundation in knowledge of useful arts and crafts—attainments Desmarest began to acquire in 1757 with his employment by Daniel-Charles Trudaine (1703–1769), the Director of Commerce—was an asset to the Academy in meeting one of its most conspicuous and time-consuming responsibilities, namely that of assessing the merits of new inventions and proposals for technological improvement, and of serving the government as an advisory body for technology. In 1785, when the Academy underwent its first major reorganization since 1699, Desmarest's appointment was changed to that of *pensionnaire* in the new class of natural history and mineralogy. Following the Academy's suppression in the Revolution (1793), and its reconstitution as the First Class of the new Institut de France (1795), Desmarest retained membership in the section of natural history and mineralogy.

⁹ Geikie (1905, pp. 159–160) emphasized Desmarest's entitlement to credit for his leading role in advocating "the doctrine of the origin of valleys by the erosive action of the streams which flow in them" through examples in a specific locality. Hooykaas (1963) made the point that Desmarest's treatment of the Auvergne phenomena invoked a form of the uniformitarian principle. Where Hooykaas argued (p. 17), however, that Desmarest "state[d] the uniformity of natural processes as a result of his investigations" rather than as an assumed basis for his interpretation, I cannot see that Desmarest's text demonstrates this very well. Rather, Desmarest appears to argue that once we accept the regularity of volcanic phenomena (as a premise), then through use of the *époques* concept we are enabled to make sense of what is seen in the field.

of the positional sequence of the different masses, and generally without special concern for reconstruction of a chronological series of events in which those masses were formed. The extent to which these initiatives were known to Desmarest when he undertook to separate the Auvergne volcanic remains into three epochs is somewhat unclear—although he certainly was quite familiar with Rouelle's teachings, and very probably he was aware at least of Lehmann's work.¹⁰ In any case, I follow the analysis of Rudwick (2005), in seeing these structurally-focused initiatives, prior to Desmarest's 1775 paper, as efforts of fundamentally geognostic character, emphasizing the *positional* relations of the different rock units identified. What mainly mattered were rules for locating distinct rock masses, a matter of practical importance in knowing where to look for extractable resources. If there was a tacit understanding that the *spatial sequences implied chronological order* as well, this was not emphasized, nor had a language of *epochs* been put into effect to discuss it.

Thus if Desmarest had multiple predecessors, in carrying out detailed local lithological research to work out the configurational distinctions among rock masses, he still appears in our eyes as having helped to open up new cognitive territory by trying to convert the results of such research into an understanding of a temporal sequence of events for a given locality.

A salient aspect of this effort was Desmarest's 'analytical method' (previously pioneered by Steno)—with its emphasis on working backward in time from the most recent, and therefore least disturbed, volcanic remnants to the products of earlier eruptions. Desmarest reasoned in reverse-chronological order, gauging the extent of the lavas' erosive alteration on the basis of comparison with well-preserved remnants of comparatively recent volcanoes. (Throughout the remainder of his long scientific career, Desmarest repeatedly proclaimed the advantages of studying volcanism in a place such as Auvergne, where—as he was instrumental in establishing—it was evident that volcanic activity had occurred over a considerable period but had ceased relatively recently, in preference to localities where volcanic eruptions are in progress but past activity is obscured.) To stress the efficacy of working in reverse order of time, he counted 'forward' toward the past, enumerating the three epochs starting with the most recent and intact volcanic remnants, and proceeding toward increasingly disturbed and thus more confusingly arranged features. Thus Desmarest advocated, as part of the geological enterprise, the imaginative reconstruction of a terrain in states prior to its destruction.¹¹

Also noteworthy in Desmarest's discussion was his recognition that ordinary agents of erosion acting over long periods had worked vast changes in the Auvergne landscape. In judging that such changes had happened in proportion to the lapse of time, he expressed the view that denudational processes operate constantly and gradually.

Avoiding specific time estimates, he nonetheless made plain his belief that the volcanological and physiographic alterations necessitated by his interpretation must have occurred over periods dwarfing the scale of human historical knowledge.

While evidently aware that analysis by *époques* offered the prospect of making natural history more truly historical than it had heretofore been, Desmarest indicated that his main interest was in using such analysis as a tool to gain a deeper understanding of the operations of volcanoes. His convictions about volcanoes were in certain key ways rather conventional. The paper translated below reflects his steadfast adherence to a theory of volcanism commonly held at the time, as a comparatively shallow and somewhat restricted geological phenomenon: it emphasized the study and classification of igneous products in terms of their supposed derivation from 'primitive' or original materials (mainly granites) that local volcanic heating had altered to varying degrees. However, through his 'theory of *époques*' Desmarest was evidently modifying his ideas about volcanoes somewhat, increasingly viewing volcanic phenomena as a permanent factor in the overall framework of global operations.

Through the remainder of his long scientific career—Desmarest was assiduous in his attendance at the Academy's meetings until shortly before his death in 1815 at the age of ninety—he exhibited interest in integrating his concept of *époques* into the broad framework of geological understanding, using it, for example, in his treatment of alternating incursions and retreats of the sea.¹² However, he appears never to have embraced fully the determination of historical successions as an end in itself; he never re-oriented his thinking to the extent of reconceptualizing the central objectives of what we now call geological science in essentially historical terms.

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¹⁰ Desmarest attended Rouelle's course of lectures in chemistry in Paris (which were not oriented toward mining concerns) in the early 1760s. Although no evidence is known to show that Desmarest met Arduino during his Italian journey of 1765–1766, it seems likely that he learned about him no later than that time. Surely he must also have been aware, by 1775, of Lehmann's work, which was translated into French by d'Holbach in 1759.

¹¹ In his later and fuller republication of his paper on Auvergne *époques* (read at the Institut de France in 1804, printed 1806), Desmarest accepted a reversal of the 'analytical order', and adopted the emerging convention of designating periods in chronological order. Among the most conspicuous differences between the 1779 excerpt and this later republication, the 1806 article included place-specific commentary illustrating the *époques*' distinctions in Auvergne, with four maps; and it elaborated on the application of his 'theory of *époques*' to localities other than Auvergne, especially in Italy.

¹² See for instance Desmarest 1794–1828, articles '*Analyse du globe de la terre*', vol. 2 (1803), pp. 493–497; and '*Méthode d'observation pour la distinction des époques de la nature*', vol. 4 (1811), pp. 606–608; also Desmarest 1806, pp. 235, 243–245, 255, 273–275.

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First English translation of Desmarest's paper of 1779

Nicolas Desmarest

Extrait d'un mémoire sur la détermination de quelques époques de la Nature par les produits des volcans, & sur l'usage de ces époques dans l'étude des volcans.

Observations sur la physique, sur l'histoire naturelle et sur les arts, v. 13, 1779 [February], pp. 115–126.

[115] Excerpt of a memoir on the determination of some epochs of nature through volcanic products, and on the use of these epochs in the study of volcanoes.¹³

By M[onsieur] Desmarest.

Having applied himself especially to study of the extinct volcanoes of Auvergne, M. Desmarest soon perceived the need to order and classify the different igneous products, according to the extent to which they had been heated, and in relation to the primary materials that had served as the basis of the melt. He saw plainly that it was by lack of such valuable categorization that observers who had published some facts relating to the operations of heat in burning volcanoes consistently limited themselves to highly uncertain assertions. Once this first step was taken, he concerned himself with the distribution of volcanic materials over the surface of the areas ravaged by fire. It troubled him to see that certain observers, in noting the existence of extinct volcanoes, had not delineated precisely the outlines of the craters and the lava flows emanating from those craters. In their writings he found treatments to be more of volcanized districts than of volcanoes, and more of disordered products of fire than lavas and flows emerging from specific centres of eruption. To get around these problems, he believed it important to re-establish his observations and their implications at a level of precision, sufficient to ensure that the study of Nature could be a science capable of occupying a sensible man. The work on the epochs of different igneous products is the result of this methodical manner of proceeding, which he believed it essential to follow in making his observations. We publish it all the more eagerly, as it can obviate any need for repetition by others who grasp its sense and its conclusions.

[116] After having given long study to the different products of volcanoes, and having observed and ascertained the distribution and the immense displacement of lavas around their centres of eruption, M. Desmarest found so much variety in his observed results that, far from being able to draw precise conclusions, he met with the perplexity that follows naturally from so large a number of disparate facts.

On the one hand, certain igneous productions exhibited a correspondence as regular as it was instructive: and he was able to grasp here simple and uniform conditions. Such was the case with craters whose wide and deep openings were covered with scoria, with flows enveloped by the same scoria, exiting from the lower parts of these craters. But elsewhere, he encountered so much apparent disorder in the arrangement of the lavas, and so little uniformity in

their distribution, that he was tempted to attribute this state of affairs to the paroxysms of fire, to the irregularities of heat's effects in the eruptions of certain volcanoes. However, several considerations undeceived him.

First he conceived that, volcanic conflagrations being accidents in the course of Nature's ordinary phenomena, their recurrences had not been subject to any fixed period. From this first consideration of things, he concluded, that the products of successive eruptions dispersed over the surface of certain parts of the Earth, in times more or less remote, must have undergone alterations to an extent in proportion to how long they had been exposed to the continual and destructive action of water.

Casting a glance over these diverse products, he was able to discern a series of regular alterations, confirming these first notions. Then, through a more detailed comparison of the simplest phenomena—that is, a comparison of the original forms of the latest igneous products, with the various alterations shown by these products, in certain cases displaying quite distinct gradations—he soon realized the necessity and the benefits of classifying the facts connected with certain states of the volcanic materials, and of adopting as a way of appraisal an analytical method based on examination of alterations and on comparison of these alterations with the condition of the volcanoes' original state. In this way he succeeded in setting within precise limits each of the corresponding and parallel features that developed or changed proportionately.¹⁴

As a result of this way of thinking and arguing, he was enabled to discern in the volcanic eruptions—the products of which were known in given circumstances or in certain particular configurations—their *epochs* and ages, for which he could determine at once the organization, the succession and the bounding limits. Thus he understands by *epochs* the joining of certain *circumstances* and certain *states* in which Nature's productions are found, such that [117] it is possible to determine, not the exact date, but the sequence of events that gave rise to those productions.

As these epochs distinguished by M. Desmarest are founded solely on the consideration of monuments of Nature, which have nothing or almost nothing in common with historical monuments, he gives no consideration here to periods known or conjectured about through civil history. In his work, the revolutions of Nature are established by their traces, and by their still extant remains.

The recognition of distinct epochs by M. Desmarest, being the outcome of factual analysis, has put him in a position to resolve, in a simple and natural manner, the main difficulties that he had encountered through an initial examination of volcanized terrain. Also, he was soon convinced, by the use and applications he has had occasion to make of it, that it was by virtue of not having identified these epochs that so many useless facts had been gathered [by other investigators]—facts as poorly determined as they were interpreted—the confused assemblage of which could only obscure the natural history of volcanoes. With this [Desmarest's] method, by contrast, not only can one proceed sure-footedly in research on fragments of this history, one can also link the parts together to form a whole which, although incomplete, makes clear that Nature has been subject to the same course in the remotest ages as in the most recent times.

¹³ [Desmarest's note:] The Memoir, the excerpt of which is given here, was read at the public session of the Royal Academy of Sciences, at the Saint Martin's reassembly, 1775.

¹⁴ Desmarest's reference was to correspondences between the extent of a lava flow's erosive degradation, and its topographic position relative to the bottoms and crests of valleys. See his discussion of this point on p. 119 of his text.

Beyond the great expediency he found in the distinction of epochs, for reconciling observations concerning the effects of subterranean fires, as another immediate consequence this same distinction also furnished him with some leading facts that have served to establish the solution to a great number of questions on the physical history of the globe.

From these points, the purpose of this memoir should be apparent. M. Desmarest first shows the different *conditions* [*circonstances*] that have appeared to him as characterizing each of the epochs, and as supporting the distinct place and the order he has given them. Then, he identifies the different localities where he has observed and recognized the *conditions* indicating these epochs. Finally, he points out the consequences that can be shown and the applications that can be made, whether in the study of igneous products or in several interesting points regarding the globe's natural history.

The factual analysis that brought M. Desmarest to discern different epochs in igneous products also led him to understand the order he ought to follow in the examination and exposition of the conditions characterizing each of these epochs. He settled first on the epoch encompassing the most recent operations of fire. This analytical way of proceeding is based on this principle, that the results of Nature's latest operations are simpler and less altered by daily changes that befall objects in their original state; [118] and that agents are the more easily recognized when the marks of their action are more evident. Moreover, this unaltered state provides a basis of comparison that should be continually kept in view by the observer if he wishes to judge securely on the extent and progress of successive changes.

First epoch

In accord with these views, the first epoch that he identifies is that encompassing the products of active volcanoes, or the most recently extinguished.¹⁵ It is around these openings, still exposed, that the distribution of melted materials is most easily considered, where one best understands their different states and the mixtures encountered there, and one becomes accustomed to discovering the disposition of all the parts of these great and vast laboratories. The signs and characters of this epoch are as follows. First, the rounded form of the mountains, showing at the truncated summit a wide and deep crater or opening. The interior of the crater and the outer rim are covered with scoria or light, perforated lavas, and by baked and porous materials. Second, the lava flows that are exposed on a mountain's open flank, and spread over the neighbouring level ground, are composed of a lava that is compact at the centre, porous and crowded with blisters on the surface; furthermore, they are accompanied and covered, over their entire length, by scoria, baked earth and pumice, similar to those covering the crater. Third, an important circumstance is that these flows are subject to all the uneven features now present on the land surface in the vicinity. This is seen, for instance, near the Puy de Dôme in Auvergne: flows which, having been extended over an elevated plateau, have proceeded down into the low flat ground, following the slope and watercourse of the valleys that lead there, to occupy the bottom of these valleys and flat-lands, more than two hundred fathoms below the level of their point of origin [*foyer*], and more than two leagues from this same centre of eruption.

These flows display yet another interesting peculiarity: they were formed, so to speak, in a single surge, from the volcano to their most

distant extremity. That is, their continuous mass appears not to have been cut or divided by any new channel.

Assimilating the features of igneous products belonging to the first epoch, these are easily noted in the craters of various depths and covered over by masses of scoria, and in the lava-flows enveloped by the same scoria, occupying the valley bottoms without substantial break or interruption. But this consistency of condition hardly applies beyond the earliest periods of this epoch. [119] M. Desmarest has judged, moreover, that within the limits of this first epoch one should also include the alterations withstood by the craters, scoria, and the flows themselves, relative to the different positions they have taken in the valleys. All these appearances are manifestations of changes that visibly proceed at similar rates [*qui ont sensiblement les mêmes progrès*]. Once one perceives craters whose edges are rounded or widened, or which have begun to fill in, once the scoria decompose into a pulverized earthy substance, then the flows emanating from those centres of eruption no longer occupy the valley bottoms. They are instead located part-way up the slope, the valley having been deepened after the flow came to be established on its former floor; and finally one notices in the length of the flow some breaks and interruptions of modest scale.

Second epoch

If one follows the course of all these effects which apparently proceed in parallel, one arrives at a state where scoria are no longer found, nor porous baked materials, where the craters have disappeared completely, where the flows are located on elevated surfaces, and where different parts of these flows are divided by wide, deep valleys. By these qualities M. Desmarest recognizes the *second epoch*, and it is by all such features that he designates it.

This rapid summary of what distinguishes the *second epoch* shows that M. Desmarest was brought gradually to recognize it following a strict and methodical examination of the alterations and changes displayed in the volcanized materials of the first epoch's closing periods. It also shows that the marks of this second epoch are, actually, just the results of more complete alterations, the proper appreciation of which required the same analytical way of proceeding, and the same basis of argument that M. Desmarest had initiated for the first epoch. But to provide even stronger warrant for the accuracy of this scheme, let us go back with M. Desmarest toward the origin of things.

If, throughout the whole of time, volcanic fire has manifested itself in the same fashion; if its eruptions have issued by way of huge vents; if the materials melted by the action of the conflagration [*flamme*] were first confined within a quasi-crucible [*creuset factice*] and then were discharged to the exterior through the opened flanks of the volcanic mountains that functioned as the crucible; it is evident that the igneous products assigned to the second epoch must at one time have appeared in the same primitive forms as those of the first epoch, and in perfectly similar circumstances. And, judging by what is left [120] in view, it cannot be doubted that there were then open craters, scoria, and continuous flows covered with scoria and located in what were formerly the lowest parts of the terrain, toward which melted materials always lead as they follow declivities favorable to their flow.

It is therefore only through the long succession of ages, that all these forms and features have changed. M. Desmarest shows us the

¹⁵ Desmarest's inclusion of active volcanoes within the first epoch indicates his intention (conveyed also in his article's title) of proposing a scheme that could apply to other localities besides Auvergne, where he certainly believed no volcanic activity was in progress.

causes and development of these changes. Observation teaches us, first, that the scoria and baked and porous earths undergo a quite discernible disintegration, and at length are reduced in a short time to comminuted earthy substances. Moreover, it shows us that waters from rain and melted snow continually displace these mobile materials. As a result of this double action of water, the sides of the craters, formed in great part of scoria, must have become worn down; these openings must have become filled in by insensible stages, and must finally have disappeared entirely, so that nothing remains in their place except mixed masses of powdered clots, remains of different products of fire, or of masses of compact lavas, which, not having been extruded at the time of the volcano's extinction, were cooled within these vast crucibles, and there formed residua [*culots*]¹⁶ of various sizes. Thus, when the craters' destruction is complete, nothing more is found, in the place of the wide and deep opening, than the debris of light lavas mixed with compact lavas; or else masses of compact lavas raised and scarped on all sides. These are [so to speak] *culots* whose furnaces and crucibles have disappeared. Here, then, is where analysis of the facts has led M. Desmarest. The same is true of the flows emanating from the centres of eruption: in the original state they must have been covered with scoria but now they have been reduced merely to compact and solid lavas; the only things on display in the crevices of these lavas, and in the interstices of the different beds accumulated one on top of the other, are the powdered materials that have been discussed previously.

Here is another change that must have arisen from the same causes. The flows that had covered the lowest parts of the surfaces adjacent to the centres of eruption have come to be situated, by the progressive excavation of ravines and valleys, on elevated plateaux, and through the inevitable consequences of the work of water these flows have been cut up and divided into different parts in proportion as the valleys have been multiplied and deepened. So in order to recover the former continuity [121] of these flows, one must [in one's imagination] largely fill in all these valleys, and reconstruct the floor that once lay beneath the flowing of the lavas.

Thus the igneous products in this second state no longer have accompanying scoria. An open crater is no longer to be seen at the flows' point of origin. The only way of recognizing the centres of eruption is to find the common origin of multiple flows; it is from that elevated point that the flows seem, by following favorable declivities, to have been distributed on the surrounding surfaces, covered with their spread-out lavas. The centres of eruption are also often marked by the huge *culots* of melted materials of which we have spoken.

Since the flows of this epoch are now always situated at high levels, occupying even some flat summits of isolated promontories, as a consequence of this disposition one often sees their profiles running the length of the upper rims of the valleys that were excavated in the masses of these surfaces. It is even quite common to see portions of a single flow situated on the two opposite and corresponding sides of a valley. And one is easily persuaded that these different masses of lava have been cut and separated by these valleys, and that they formerly belonged to a single continuous entity, when one takes into consideration the similar grain of the lavas, the form and scale of the basaltic prisms involved in the flows, the number of levels and rows of these prisms, which are the same on both sides of the valley; and

finally if one reflects on the required solid foundation for the movement of the lava the whole length of its flow.

This set of conditions regarding the second epoch seemed of great importance to M. Desmarest, in relation to the conclusions he believed he was entitled to draw from it. He deduced an evident principle through establishment of a single fact—namely that the lava flows, during the time of this epoch, spread over high surfaces before any valleys had been excavated in the mass of those uplands. And he concluded from this that these flows were formed prior to the deepening of the valleys, since they could have moved to the extent that they actually did only if the empty spaces of the present valleys had been filled.

Here is yet another feature connected with this epoch: all the flows dating from this period are similar—especially toward their lower extremities—in having covered over granitic masses, as the surface of the highest horizontal beds. When this is the case, it is evident that the flows are subsequent to the formation of the horizontal beds. M. Desmarest grasped this conjunction regarding the horizontal beds, insofar as they are found covered by lava flows of the second epoch, as a simple way of [122] fixing them precisely in time; and as an immediate consequence, the period of the deepening of the valleys is determined to be subsequent to the distribution of the flows, overlying the previously formed beds.

Third epoch

This same consideration regarding horizontal beds also led M. Desmarest to the third epoch. And to distinguish this epoch, he need[ed] no more than the relative disposition of the horizontal beds. As we have seen, in the second epoch, the beds are always covered by igneous products. In the third, on the contrary, the beds cover these igneous products or are mixed with them. The areas where igneous products belonging to the third epoch predominate, displayed on all sides to M. Desmarest masses of lavas buried under a combination of horizontal beds, either composed of calcareous and argillaceous substances entirely unaltered by fire, or else formed of volcanic materials that the sea has deposited in layers mixed up with *beds* of the unaltered [*intactes*] materials. Also seen among these deposits are very thick beds of rounded pebbles composed of lavas of various kinds.

Any mass of lava covered by continuous horizontal beds must have been melted and then cooled before the sea could have formed these deposits. For otherwise the igneous eruptions and the explosions of igneous materials that usually accompany the melting of lavas, would have overturned the beds that had covered them, and, in their distribution, would have produced a disorder that is easily imagined and of which moreover one could cite more than one example. Now, none of these disturbances is seen in the greatest part of the horizontal beds that cover or envelop the masses of lavas. For in Auvergne and in Italy where the marine deposits covering or enveloping the enormous lava masses sometimes have a thickness of a hundred, and even one hundred fifty fathoms, the lowest beds that rest upon the lowest lavas are as continuous and as regular as those that rest on the highest parts of the lavas. Here then is a thickness of nine hundred feet of horizontal beds that must have been formed tranquilly in a sea basin, without having undergone the least disturbance from

¹⁶ [Desmarest's note:] The term *culot* refers to anything which, in the melting of metal-containing materials, is found at the bottom of the crucible, separated from the scoria.

subterranean fires. All these masses of lava were therefore melted and in place, before the sea had formed any part of the deposits that overlie them. M. Desmarest does not, one may add, maintain that all lavas covered by horizontal beds date from the beginning of the sea's presence in the areas where these masses are on display. On the contrary, he points out products of eruptions that took place during the sea's presence. He has found flows of [123] quite compact and solid lavas emplaced above the horizontal beds, with these overlain in turn by a number of similar beds, deposited upon these lavas. The soft paste of shell debris filled, with precision, the openings in the scoria and porous lavas spread over the flow's surface. These melted materials are sometimes located near the middle of the total thickness of the horizontal beds. Thus, since the eruption of the volcano that produced these lava beds, the sea has tranquilly formed a thickness of deposits of around a hundred fathoms. We omit here several other equally decisive proofs, and in particular those masses of bitumen [*poix*] which, in Auvergne, are embedded within the horizontal beds of unaltered [*intactes*] limestones, and occupy different levels therein.¹⁷ They are found in the vicinity of certain horizontal beds composed of a mixture of calcareous materials and thoroughly disintegrated volcanic substances.

Consequences of these epochs

Having ascertained the conditions in which igneous products are found for each epoch, as well as the succession of these epochs following the analytical order he adopted for his investigations, M. Desmarest then reverses this order and takes up these epochs so as to consider them according to their natural succession in time.

The oldest epoch is now the first in order, but which he continues to call the *third*. This epoch gives evidence of several eruptions of subterranean fires having melted enormous masses of lavas, before the formation of the horizontal beds, and before the incursion of the sea itself. Further, these fires underwent attacks and repetitions during the time that the marine incursion lasted. The limits he has determined for this epoch include a certain portion of the time that preceded the presence of the sea in these areas, in addition to the entire time of the sea's presence. Thus there are here two quite distinct periods [*âges*] within a single epoch. The latter one certainly includes whatever time Nature required to form a thickness of from a hundred to one hundred fifty fathoms of horizontal beds overlying the lavas.

In the succeeding epoch, which is the *second* according to his analytical order, M. Desmarest shows us the lavas running unobstructed over the surface of the granite masses and horizontal beds, and flowing over the whole extent of the uplands, where they came to rest on unbroken ground without any significant openings, and without valleys of any great depth. This epoch therefore comes later than the formation of the horizontal beds, for volcanic products overlie them; and it is prior to the excavation of the valleys, since the lavas belonging to this epoch encountered none throughout the whole distance that they flowed. Its two limits are found between [124] the horizontal beds exposed by the retreating sea and the [period of the] excavation of the valleys to a certain depth.

The next epoch, which is the youngest of all, and the *first* in the analytical order, returns us to our own time, restoring the alterations

in phenomena since the original volcanic conditions. It occupies the entire time that must be allowed for rainwater to have excavated the valleys. It even shows us the different stages of the work, by showing us the flows at all possible levels on the sloping edges of the valleys, and by indicating to us thereby that each point serving as a base and support for the flows was in its turn part of a valley bottom, at the time of the volcanic eruptions that produced the various flows.

It was in this epoch that the horizontal beds, which formed during the third and oldest epoch, were carved with ravines; that the craters belonging to the second epoch were destroyed; that the scoria that had accumulated there were reduced to earthy and powdery material suitable for vegetable growth; that the different parts of the flows themselves, laid down on the surface of the horizontal beds, were separated—as were these beds themselves—by clefts that slowly became valleys of the first order. It is this first epoch that, leading us gradually to the second, teaches us that the openings separating portions of a single flow must enlarge and deepen in the same proportion as the process of destruction of the craters and the reduction of the scoria proceeds. It is this epoch which, after having familiarized us with all igneous products, subsequently enables us to recognize them, even though there are no longer any craters or scoria accompanying them, and even though the lava flows are divided into parts and located in isolated fashion on mountain heights on all sides, or even though these lavas are buried beneath horizontal beds. Finally, it makes us realise that the study of volcanoes should not be embarked on in lands where there are no remnants of the second and the third epochs. M. Desmarest brings out this weakness in approach as the source of errors and misunderstandings by naturalists who have neither experienced nor followed this analytical way of proceeding.

It is as a result of the failure to use this method that such naturalists have denied the existence of the lavas that he [Desmarest] situates within the third and second epochs. Through this shortcoming they have classified these lavas, as well as the prismatic basalts, sometimes among aqueous deposits, in other cases among the schists, and in yet others within the class of hornstones [*pierres de corne*].¹⁸ By this mistake they have mis-identified as former craters certain widened parts of valleys that have been excavated by water amidst the lavas of the second epoch, and even of the first. And lastly, from this error, they have mistaken [125] lake basins, which are commonly found in volcanic regions, for former craters.

This last mistake provide[d] the occasion for M. Desmarest to discuss a feature of the first epoch, which he had omitted. In the regions covered by igneous products belonging to this epoch, one never sees springs or rivulets of running water on the surface of volcanic materials. The craters are all dry. It is easily conceived that the masses of scoria covering the lava flows provide openings everywhere that facilitate the filtration of rainwater through all the flows. This water collects then on the solid horizon serving as the flows' base, and appears only at their extremity, where it issues in copious springs.

It is not necessary to show here how weakly founded is the supposition of those who have placed lakes in former craters. It suffices to say that often they have situated the lakes in places belonging to the second epoch, where craters are certainly no longer to be found,

¹⁷ Later, in his comprehensive *Géographie physique*, Desmarest identified the mineral pitch or *poix minérale* he said was abundant in Auvergne—a form of solid petroleum or tar called *malthe* or *pissasphalte*—as one of five distinct types of bitumen: article '*Bitumes*', vol. 3 (1809), pp. 148–152.

¹⁸ *Pierre de corne* (sometimes *roche de corne*) or hornstone—*Hornstein* in German—was a term applied during the eighteenth century to various sorts of rocks, always hard, and often described as dark and refractory or resistant to the effects of fire. Sometimes it was identified with flint (*silex*).

and never in those of the first epoch, where there exist some very obvious ones.

In places where igneous products of the second epoch dominate, where scoria are reduced to a highly comminuted substance susceptible to a certain compression, rainwater does not penetrate as deeply as in the localities of the first epoch. Some rivulets are noticeable in the second epoch, but craters are no longer found there. Lake basins here are always placed either upon unbroken ground that holds water or on baked substances worn down to earth. As for the sides of these basins, they are formed either by an assemblage of horizontal beds such as those of Lake Bolsena,¹⁹ or by the confluence of several flows that seem to have surrounded the basin without filling it.

We are in position to add to all these details several other considerations on these three epochs, particularly on the means used by M. Desmarest to connect together the time when lavas covered only the granitic lands and the time when lavas flowed over the horizontal beds. However interesting these might be for establishment of his full doctrine, we leave them aside here. We also overlook here the descriptions from throughout France and Italy that have provided him natural evidence of these three different epochs. As regards Auvergne, we refer to the *Memoir on Basalt*, published in the *Mémoires* of the Academy of Sciences for the year 1771. The distribution shown there for lava flows of three main classes, is based on the same [126] features that served him in distinguishing the epochs. It is easy to see that the entire doctrine we have just outlined, resting on these facts, can very usefully be applied both to the study of igneous products and to the study of several interesting points of the natural history of the globe.

We shall indicate here, for example, the use that can be made of these epochs to judge the development and extent of destruction undergone on certain parts of the Earth's surface by the action of water and the alternation of seasons. Let two lava flows be examined, one belonging to the first epoch and the other to the second. It is easily seen that in covering certain parts of the Earth's surface at different periods, and consequently by the different conditions through which this surface has successively passed, these lava beds have retained the form of the ground that served as their base, such as they were at their respective epochs. Taking into account, then, the order of epochs relative to the lavas, the same order of epochs can be assigned in relation to this or that form of the general surface of a certain region, and the extent of the changes that the lapse of time separating the two epochs has been able to produce on this surface can be estimated. For the evidence of these changes lies beneath the lavas. If, on the other hand, one compares the parts overlain and protected by the lavas with those in the area that have remained uncovered and exposed to the destructive action of the waters it will be seen that often the level is reduced, in these latter parts, some 150 and even 200 fathoms below the level of the first; and that instead of showing, as do the parts covered over by lavas, an upland with a uniform surface, the disordered granite masses, abundantly carved

by ravines, give evidence of immense destruction through the debris of all kinds by which they are covered. In this way comparison of the covered parts of lava with those left exposed everywhere provides interesting contrasts. The varied evidence of these successive changes undergone at the Earth's surface, preserved in the lava, is thus as valuable to a naturalist as are, for the devotees of a more modern antiquity, the products of human art conserved in Herculaneum beneath a covering of similar materials.²⁰

Comments on the translation

Although short segments of Desmarest's essay have appeared in English translation in scholarly works (Geikie, Hooykaas, Rudwick), I know of no previous translation of the whole. A three-paragraph passage from Desmarest's expanded 1806 publication appeared in English in Mather and Mason (1939, p. 91). While I have of course had occasion to consult these previous translations, the one presented here is my own. I have tried to render Desmarest's text in a way that is both faithful to its meaning, and readable. (Accomplishing both at once is a bit more difficult than might be supposed, by anyone who has not tried it—or who is not familiar with the conviction expressed in the Italian aphoristic pun, *traduttore, traditore* [essentially 'a translator is a betrayer'].)

I judged it best to allow translations of certain terms in varying ways, depending on the circumstances. For example, the French *feu* is sometimes 'fire', sometimes 'heat'—while the expression *produits du feu* is usually 'igneous products'. *Plaines* is translated in different situations as 'flat-lands', 'surfaces', 'levels', 'ground', or 'uplands'. For *Vallon*, meaning a small valley, it was tempting to use the archaic English word 'vale', but in most instances it seems better to choose 'valley', while rendering it at certain points as 'channel', 'ravine', or 'opening'. A comparable but somewhat less clear-cut set of choices arises for the word *circonstances*: often this is translated as 'conditions', but on certain occasions as 'circumstances', 'features', 'appearances', or 'conjunction'.

Terms italicized in this translation correspond to French words italicized in the original text. The word *Nature*, consistently capitalized in the French original, is rendered the same way here. (On the other hand, although Desmarest nearly always capitalized *Volcan* and *Observateur*, these are rendered in lower case in the translation.) At a few points in the translation, additional words or endings are interpolated, in brackets, to facilitate understanding. Where a translation is notably problematic, the original French word or expression appears, italicized and in brackets, following my choice of translation. The main units of measure that appear in the text are given by their English equivalents: a *toise* of six feet is a 'fathom' and a *lieue* is a 'league' (three miles). The two footnotes included in Desmarest's original article are identified with a bracketed notation. All the other footnotes are mine. While Desmarest's text was originally published as a third-person account, as seen in the translation, the version published in 1806 was done in the more conventional first-person fashion.

¹⁹ Located in west-central Italy, near the northern boundary of the Lazio region, north of Viterbo and southwest of Orvieto, Lake Bolsena is of roughly oval form, with a diameter averaging a little over twelve kilometres. Desmarest had seen it in 1765.

²⁰ The ancient Roman town of Herculaneum, buried in the great eruption of Vesuvius in A.D. 79, became the site of excavations (and looting) following the chance discovery of parts of its ruins in 1709. During the middle part of the eighteenth century, scholars and artistic connoisseurs took great interest in the excavations at Herculaneum and nearby Pompeii—developments through which the discipline of archaeology achieved higher levels of refinement and of 'historicization'. In this final sentence, Desmarest struck a note frequently expressed by geoscientific naturalists at the time: the analogy between the study of artifacts to understand human history and the examination of natural evidence to understand the Earth's past. In the contemporary vocabulary, both kinds of evidence were commonly referred to as 'monuments'.