Three early arguments for deep time—part 2: volcanism

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Well before 1800, European intellectuals embraced an unbiblical prehistory. One of the three major arguments advanced to support this prehistory was the time needed to construct Vesuvius, Etna, and other volcanic terrains, relative to the size of observed eruptions. Proponents of this argument assumed a constant rate of volcanism through time and extrapolated from small eruptions that were not representative of global volcanic activity. They also were unaware of examples demonstrating much higher rates of volcanism in the past. Although modern geologists acknowledge these shortcomings, they do not appear to grasp their evidentiary impact. If modern examples and those from the rock record support rapid rates of volcanism, contrary to the vast prehistory of Enlightenment imagination, then the original argument is invalid. Thus, since prehistory was never later questioned, it must either be an assumption or the product of circular reasoning.

Evidentiary logic demands that a conclusion be abandoned if its original evidence is invalid. New arguments can be made for the same proposition, but if the original faulty conclusion is assumed in that argument, then the reasoning becomes circular. Like a courtroom appeal of an old case, the first verdict is set aside and the case is retried. Deep time was affirmed initially based on faulty evidence, and was never subsequently 'retried'. Once early naturalists claimed to have proven prehistory, they never looked back. New evidence was added after the fact, but no-one ever seriously attempted to reassess the original conclusion. Thus, deep time—the foundation for secular natural history—is either a faith tenet or the product of circular reasoning. Radiometric dating, magnetostratigraphy, biostratigraphy, and similar modern methods were never used to evaluate deep time, but only to 'confirm' what everyone already 'knew'.

The original argument for an old Earth, and subsequent rejection of Genesis, included three primary lines of evidence offered during the second half of the 1700s. These included the time needed for valley formation, for the construction of volcanoes, and for the accumulation of the sedimentary record.[1] The argument from valley erosion is invalid.[2] If the same is true of the arguments from volcanism and the sedimentary record, then it is not unreasonable for us to conclude that prehistory was an axiom flowing from anti-Christian bias.

This paper will address the second argument—the time demanded by the gradual accumulation of lava and ash. Using rates observed at eruptions of Vesuvius and Etna, 18th century naturalists argued for lengthy periods of time to build those mountains and to create larger volcanic terrains, like Auvergne and Campi Flegrei.

A few preliminary clarifications are needed. First, there was no great struggle between secular naturalists and the church. Even self-described Christian intellectuals that defended the Flood were convinced Earth was old. Second, our present conception of geology is anachronistic to the late 1700s. Though 'geology' was introduced as a term in 1778, it had a different meaning. Earth sciences included three categories: natural history, natural philosophy, and geotheory.[3] Studies of volcanoes fell under natural history and natural philosophy. Broader speculation was the role of geotheory—an attempt to explain Earth as Newton had the secrets of light and gravity. The works of Buffon and Hutton[4] were examples of geotheory.

The argument from volcanoes

Eighteenth century savants[5] argued that the biblical timescale was untenable because more time was needed to produce volcanoes, valleys, and strata. During the latter 1700s, volcanoes were intensely studied by naturalists; their grand tour included Vesuvius and Etna (figure 1). The volcanic region of Auvergne, in southern France, also became a prime field site. They believed that "Volcanoes provided some of the best evidence for such natural rates, and the most intensely discussed."[6]

The argument was simple; savants compared the volume of observed eruptions to the size of large volcanoes—Etna reaches 3,350 m (10,991 ft). They then concluded that the volcanoes must be much older than the biblical chronology:

> "Although the eruptions [of Etna and Vesuvius] were irregular and notoriously unpredictable, the records did give savants a rough sense of the rate at which those great volcanic cones might have accumulated, and hence of their overall age."[6]

A survey of some of the leading naturalists studying volcanoes and volcanic terrains at this time illustrates a remarkable bias towards an old Earth that was brought to the evidence. In other words, I will argue that these naturalists had already decided that Earth was ancient, and that this position drove their study of physical phenomena.

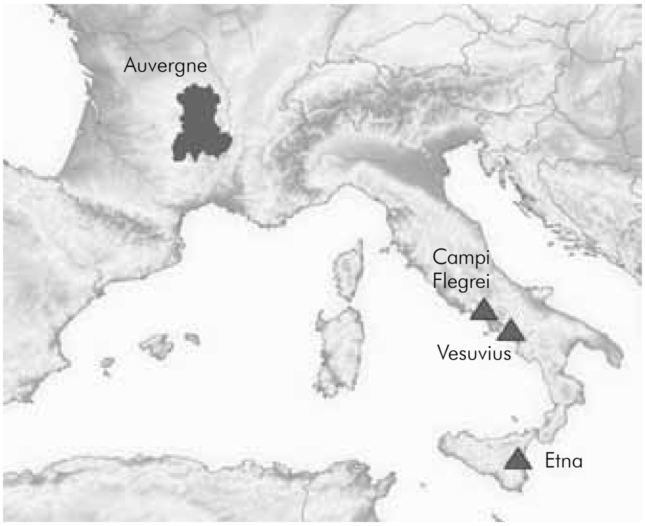

Figure 1. The rediscovery of Pompeii in 1738 stirred interest in volcanoes. Mount Etna in Sicily and Mount Vesuvius near Naples were the two largest, most accessible active volcanoes in Europe and the subjects of intense interest by naturalists of the late 1700s. The inactive volcanic cones, flows, and beds of Auvergne were the primary locale for naturalists interested in volcanics from the mid-1700s through the early 1800s.

Hamilton

Sir William Douglas Hamilton (1730–1803) was the British ambassador to the Spanish Court of Naples from 1764 to 1800. An avid naturalist, he studied Mt Vesuvius[7] and the surrounding area, ascending the mountain 65 times. He published many articles and a book,[8] which established him as a leading expert.[9]

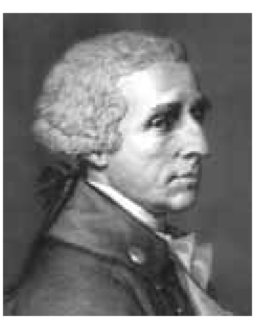

Figure 2. Sir William Hamilton (1730–1803)

Vesuvius is a composite volcano built on the caldera of the Mount Somma volcano, reaching 1,281 m (4,203 ft), with a base roughly 9 km (5.6 miles) across.[10] It is thought to be 17,000–24,000 years old, and is famous for the AD 79 eruption that buried Pompeii and Herculaneum. Considered one of the most dangerous volcanoes in the world, it has erupted frequently, though irregularly, throughout recorded human history, exhibiting both Strombolian and Plinian eruptions.[11]

Hamilton's work was primarily natural history—the description and classification of what he observed. But he also drew geohistorical and causal conclusions about what he saw:

> "For example, Hamilton became convinced that Vesuvius, and indeed the Campi Phlegraei [fields of fire] as a whole, had been an active volcanic region long before recorded history. The flooded crater on the island of Nisida, for example, offered a peaceful scene that was surely far removed in time from the ancient eruption that had formed it. Closer to the present, and vividly linking the human timescale to Nature's, were the buildings of Pompeii, buried eighteen centuries earlier in the first recorded eruption of Vesuvius, and being excavated in Hamilton's time to the great excitement of savants and the wider educated public throughout Europe. For Hamilton found that they were standing on volcanic rock, proving conclusively that Vesuvius must have had still earlier *prehistoric* eruptions."[12]

Hamilton noted early in his volume:

> "… Mount VESUVIUS … and Mount ETNA … were as evidently formed by a series of eruptions or Volcanick [*sic*] explosions, in the long course of revolving ages … ."[13]

Since Hamilton adduced a great age for Vesuvius, it is clear that he rejected biblical history. In Rudwick's[14] discussion, there is never any indication that he considered the merits of the biblical chronology. Expecting deep time, he saw it by extrapolating eruptions he observed across time. His flawed logic and bias is seen in his hasty conclusion that the presence of volcanic rocks beneath Pompeii disproved the Bible.

Hamilton was also familiar with Mt Etna in eastern Sicily which was "not only the largest active volcano in Europe but also the most fully documented volcano anywhere in the world."[15]

As expected, he arrived at the same conclusion:

> "… we may conceive the great age of this respectable Volcano."[16]

Thus, he was drawing a conclusion about earth history based purely on the physical features of Etna, rather than relying on the written historical record in Genesis:

> "But as Sir William Hamilton had noted … some of the minor cones of volcanic ash on the flanks of Etna, and the lavas that had flowed from them, appeared to be much older than any human records, suggesting an unimaginable antiquity for the huge volcano as a whole."[15]

This Enlightenment bias was widespread:

> "Hamilton's compatriot Patrick Brydone had

Figure 3. Vesuvius erupting, December 1760–January 1761. From Hamilton (1776, plates X and XII), from Meyer-Roux (2010).

gleefully trumpeted abroad the quandary in which the local naturalist (and priest) Giuseppe Recupero had found himself at that time, since any vast antiquity seemed incompatible with the traditional short timescale for the earth that was still taken for granted by Recupero's bishop, though not by savants. However, decades later, when Recupero's book on Etna was published at last, worries about the earth's timescale were much less of a problem, *even in benighted Sicily* … [emphasis added]."[15]

Brydone was no objective empiricist; his attitude was clearly anti-Christian. Evidence from Etna was not carefully considered; deep time was simply taken for granted (using the gradualist assumption that long predated Lyell). Brydone had no way of knowing how old the volcano was. His bias was shown in his attack on naturalist/priest Giuseppe Recupero (1720–1778). Note the admission that an extended timescale was 'taken for granted' by savants, and Rudwick's own bias is seen in his characterization of Sicily as 'benighted'.

Ironically, it was Recupero who offered actual empirical evidence to support the longer time-scale:

> "Recupero told him [Brydone] that a well dug recently on Jaci … on the lower slopes of Etna had penetrated no fewer than seven successive lavas, each with an upper surface weathered into a fossil soil. Anyone familiar with volcanoes knew how very slowly any lava surface became weathered enough even to begin to support vegetation; the flow of 1669, for example, was still almost completely barren after a century … . With the benefit of that local knowledge, Recupero estimated that it would probably take more than two thousand years to generate a substantial soil on any surface of lava. So his well section along—a miniscule fraction of the pile of lavas comprising Etna—implies an antiquity of at least 14,000 years, more than enough to knock the bottom out of the traditional short timescale for the whole world."[17]

Sir William Hamilton was the acknowledged expert on the volcanoes of southern Italy and Sicily, although local naturalists such as Recupero were more familiar with their home turf. Hamilton argued for an old Earth from these active volcanoes, but that case was also being argued from study of the *extinct* volcanic terrain in the region of Auvergne. It became a crucial field area, influencing Scrope, Buckland, Murchison, and Lyell.

Desmarest

Rudwick called Nicolas Desmarest (figure 4) "one of the most distinguished physical geographers of his generation".[18] He made his mark in 1751, when he published an article arguing for an ancient connection between England and France. In 1763, he surveyed the volcanoes of Auvergne, noting the similarity between their basalt and that of the Devil's Causeway in Ireland (figure 5), which he had seen in Susanna Drury's (1739) painting published in the *Encyclopédie* in 1765. Desmarest set off to study the `area with cartographic engineer Francois Pasumot (1733–1804).

Figure 4. Nicolas Desmarest, a physical geographer who investigated the volcanoes of Auvergne in Southern France in the mid 1700s.

Auvergne had come to the attention of naturalists through the mapping of Jean-Étienne Guettard (1715–1786), who published the *Atlas Minéralogique* in 1780. He "… had startled savants…when he reported that there were volcanoes in Auvergne so fresh that they looked as if they were merely dormant and might still menace the region; but he had not studied the lava flows and cratered cones in any detail … ."[19] Desmarest was hooked:

> "Desmarest had shown no previous interest in volcanoes, but on seeing those in Auvergne with his own eyes he made them the focus of his research … ."[19]

While Pasumot continued mapping and collaborated in the geological field work,[20] Desmarest travelled to Italy in 1765, and saw Vesuvius, which had erupted in 1764.

> "Desmarest had embarked on travels that greatly enlarged his experience of physical geography … . But an even more decisive experience, when they reached Naples, was that Desmarest saw Vesuvius for himself. It was the only active volcano he ever visited, but it gave him a crucial point of reference for all his later studies on extinct volcanoes."[19]

Desmarest was initially interested in the origin of basalt. Based on the Drury drawing, and his work

Image courtesy of www.svr225.stepx.com

Figure 5. Engraving of Susanna Drury's 1739 painting of the Devil's Causeway in Ireland, showing columnar or 'prismatic' basalt.

in Auvergne, Desmarest concluded that the prismatic basalt was a volcanic rock.[21] It occurred in Auvergne as discontinuous beds capping hills and also as more recent flows in the valleys. These could be traced back to their cones. Desmarest published a paper on basalt in 1771, which earned him election as a member of the *Académie des Sciences* in Paris, even though his ideas about the mechanisms of eruptions showed profound misunderstandings of the physics and chemistry of volcanism.[22] In 1774 he published his final report on Auvergne for the Académie.[23] It included a preliminary map (figure 6), which he continued to refine; it was finally finished in 1823 by his son, Anselm-Gaëtan Desmarest (1784–1838). However, his ideas regarding the origin and mechanisms of eruptions and basalt showed a profound misunderstanding of the physics and chemistry of volcanism.[24]

Desmarest avoided geotheory, restricting his work to the historical reconstruction to Auvergne's volcanoes. He deduced three distinct epochs. Like his fellow savants, Desmarest was committed to prehistory:

> "The historical sciences of his time gave Desmarest powerful analogical resources for reconstructing a reliable geohistory. But his history referred to times far earlier than even the oldest human records. He stressed that his epochs had 'nothing or almost nothing in common' with those of historians, and that he would not be dealing at all with the 'known or suspected times' of human history. Even the most recent of the volcanoes in Auvergne had, he believed, become extinct long before the earliest human records in the region; human history could be tacked on at the end of his geohistory, but there was no overlap between them."[25]

Image courtesy of www.historyofgeology.blogspot.com

Figure 6. Part of Nicolas Desmarest's map of Auvergne, showing details of volcanic cones, flows, and eroded topography.

Desmarest's map influenced naturalists for decades; when Lyell and Murchison visited Auvergne in 1828, they used it to find the best exposures.

Soulavie

Jean-Louis Soulavie (1752–1813) was a French priest and amateur naturalist. He served the parish in Antraigues, near the volcanic exposures in Vivarais. His rapid rise to prominence in Paris from a rural clerical background showed Soulavie to be a brilliant naturalist. Soulavie sought a three-dimensional understanding of the strata[26] to deduce six epochs based on lithological correlations. For example, he noted that a prismatic basalt flow overlaid a gravel conglomerate with basalt pebbles. The flow was one epoch, the deposition of the gravel, another, and the basalt clasts in the gravel indicated a previous volcanic epoch.

Soulavie moved to Paris in 1780 and published an article on his research the same year.[27] He began to make a name for himself, expanding his work into a multivolume work, *Natural History of Southern France* (1780–1784). Soulavie insisted that the strata could provide the basis for a true geohistory:

> "Soulavie planned to turn his three-dimensional and structural study into geohistory, for he claimed that the pile of 'six superposed formations [*couches*]' that he had mapped were 'the products of six separate and distinct epochs.' He claimed this 'ancient history of the terrestrial globe', unlike speculative geotheoretical systems, could be founded on 'an unquestionable principle, amenable to the most rigorous mathematical demonstration.'"[28]

Soulavie's work, which Rudwick noted had 'the highest credentials',[29] was remarkably prescient to modern stratigraphy, complete with two fundamental errors. First, he assumed the distinct rock bodies represented distinct periods of time, and second, he attributed vast eons to those periods by virtue of a pre-Lyellian gradualism.

> "As with superposition, he could not assume that the idea of geohistory was familiar, and indeed he stressed its novelty: he explained how, after making 'a large collection of facts' about the present state of things, 'one can unravel nature's past epochs, and it was only in our own time that naturalists have conceived the idea of doing so.'"[30]

It is interesting to note his distortion of Christian chronology. He styled himself as 'nature's erudite historian' and talked of the 'annals of the physical world', a likely reference to Ussher's work of the past century. In other words, he saw the key to interpreting the rocks was to determine their chronology and from that build a natural history in the modern sense; a history of course that preceded humans and extended far back beyond their historical records.

Epoch 6	eruption of more recent volcanoes; time overlapped human history
Epoch 5	eruption of volcanics in eroded valleys
Epoch 4	erosion of valleys through earlier strata
Epoch 3	emplacement of sheet basalt capping plateaus
Epoch 2	deposition of fossiliferous limestone in global receding ocean ("standard theory")
Epoch 1	formation of underlying granites

Figure 7. Epochs of Vivarais region based on work of Jean-Louis Soulavie (1780).

Montlosier

Soulavie's interest in both volcanism and geohistory was mirrored by the work of Francois-Dominique de Reynaud de Montlosier (1755–1838), a landowner in Auvergne and amateur naturalist. His 1789 book, *Volcans d'Auvergne*, was overtly geohistorical:[31]

> "From that moment [of Buffon's *Nature's Epochs*], the history of the earth has started to become interesting. Erudition has appropriated nature's archives; savants have come from all parts into the provinces to interrogate its [nature's] monuments and to search its memoirs; and so geology has become a major science, to which mineralogy, assaying, and chemistry have had the honor to be subordinate [brackets in original]."[32]

Following Desmarest, Montlosier divided the volcanics into the recent cones and flows in the valleys and ancient eroded flows capping plateaus and hills. Like Desmarest, he used the current rate of erosion to estimate their age. A good observer, he noted the historical significance of a stream that had been redirected by a recent flow, carving a new valley and leaving a ponded lake behind the lava dam in the old valley. Though other geologists would use that two-fold division to argue for a deluge separating the two, Montlosier saw it as a continuous process (erosion) interrupted by sporadic eruptions. He referred to prehistory as an 'infinity of ages'. Montlosier remained in Auvergne, and later became a valuable local resource for Scrope in the early 1820s and for Murchison and Lyell in 1828.

Scrope

Auvergne would serve as a stepping stone to Lyell's synthesis. He travelled there with Murchison in 1828, but both had been drawn to the region by the earlier publications of a fellow of the Geological Society, George Poulett Scrope (1797–1876). Scrope was wealthy and could finance his interest in geology. Educated by Sedgwick, Scrope toured Italy and Sicily while still in school. After seeing Etna, Vesuvius, and Vulcano, he made the study of volcanoes his life work. After graduating, he married and took his new wife on the grand tour, visiting the Massif Central in France before continuing to Italy, where he saw the 1822 eruption of Vesuvius. As a result, "Scrope—at the age of twenty-six—probably had greater first-hand knowledge of volcanoes, active and extinct, than any other geologist in Britain."[33]

Bucking the trend against geotheory, Scrope published a book in 1825 that proclaimed that volcanic studies would lead to a new theory of the earth—one that presaged Lyell:

> "Scrope's book was notable for its trenchant insistence on the explanatory value of actual causes. With Buckland's geological 'deluge' as his obvious if covert target, Scrope criticized those who speculated about 'what *might be* rather than *what is*', and who invoked catastrophes without having first exhausted the explanatory potential of what they saw around them. He even alleged that such theorizing was harmful, on the grounds that it 'stops further enquiry' by discouraging the search for observable causes that might in fact be adequate. Instead, he urged that these causes be studied minutely, applying them to the evidence of the deep past with 'the most liberal allowances for all possible variations and an unlimited series of ages'. There was to be no shortage of deep time in Scrope's theory."[34]

Ironically, his criticism is easily applied to gradualistic uniformitarianism. Scrope followed the popular idea of a directional geohistory, based on the gradual cooling of Earth. Volcanism, he presumed, had probably been more intense in the deep past, yet he was not able to apply that idea to his own fieldwork.

Although his first book was not well received, Scrope's 1827 *Memoir on the Geology of Central France* cemented his place among the geological elite of his day. It contained abundant sketches of the landscape of Auvergne, which brought field exposures to life for those who could not go:

> "Scrope's panoramas therefore enabled his readers (or rather, his viewers) to see the volcanic landscapes *through his eyes*, as he had come to understand the terrain in the light of his fieldwork; the illustrations then became highly persuasive evidence for the geohistorical interpretations that he gave them in his text."[35]

Rudwick[36] noted that Scrope was "economical with his acknowledgements of his predecessors", especially Desmarest, whose map had been published just a few

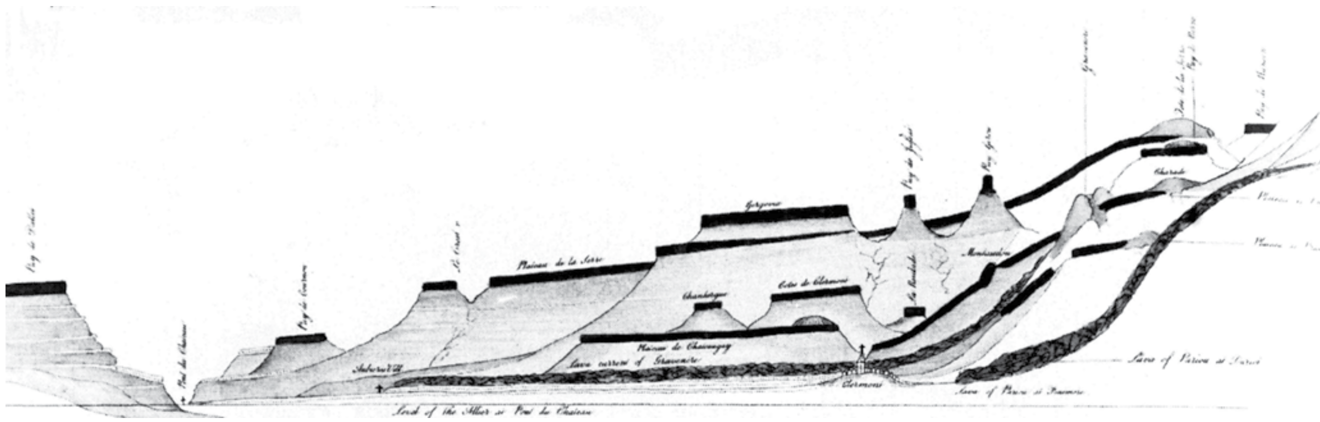

Figure 8. Cross section from Scrope[37] of basalt flows (black) from Puy de Dôme (right) down towards the valley of the River Allier. View is to the south; flows moved east off of Puy de Dôme. Scrope assumed each flow represented long periods of time.

years earlier by his son. Scrope's map was substantively similar, yet published in colour, and thus more appealing than Desmarest's. Whether from personal ego or post-war British pride, the French contribution to Auvergne's geology was minimized.

Scrope was a gradualist; he argued that observable causes acting over immense periods of time were adequate to explain Auvergne's geology; there had been no deluges.

> "Scrope argued forcefully that … the occasional eruption of lavas in central France was a happy accident that had preserved many successive phases in an otherwise steady and uninterrupted process. The moral was clear: 'surely it is incumbent on us to pause before we attribute similar excavations in other lofty tracts of country, in which, from the absence of recent volcanos [*sic*], evidence of this nature is wanting, to the occurrence of unexampled and unattested catastrophes, of a purely hypothetical nature!' … . Above all, however, Scrope realized perceptively that his inferences would be accepted only if geologists were to learn to comprehend *imaginatively* the vastness of deep time that they already claimed to take for granted."[38]

Scrope clearly had no problem with that.

Lyell

Lyell's (1797–1875) first encounter of Auvergne was through the eyes of others. He read what he could find and commented favorably on Scrope's book in the *Quarterly Review*. Lyell used Auvergne to defend his view of geohistory, and argued that theorizing was not to be avoided:

> "But Lyell implied that geohistorical reconstructions based on sound fieldwork were in a different category from the fantasies of geotheory, and it was as geohistory that Lyell introduced Scrope's new work."[39]

He thus repackaged geotheory as 'geohistory', a rhetorical move worthy of his training. But Lyell was already committing two major errors: (1) a naïve confidence that field data alone would reveal history, and (2) that Newton's method of actual causes applied to the past. That led him to conflate physico-chemical and geological uniformity, allowing him later to dismiss catastrophic actualists as 'unscientific'. Reed[40] notes that his confusion over actualism was perpetuated for 150 years, during which time no geologist ever demonstrated an univocal correspondence between uniformity and actualism!

But Lyell was not content to read. In 1828, he travelled to France with Murchison. Having talked with Buckland and Daubeny, and using local naturalists (including Montlosier), Lyell was well prepared to analyze the area. Like Scrope, he saw it through the lens of deep time, and his dogged gradualism unveiled 'evidence' of vast ages. Seeing the Sioule River had eroded through basalt flows, sediments, and into the underlying gneiss, he saw only time and 'actual causes':

> "He expressed this in a way that showed how thoroughly he had absorbed and internalized the geohistorical perspective that had already come to characterize geological argument in general."[41]

In other words, a bias towards a lengthy prehistory, accessible only to scientific investigation was ingrained into Lyell, guiding his interpretation of field data.

When Murchison left, Lyell continued into Italy, to Naples and Sicily. He saw Campi Flegrei, and climbed Monte Somma and Vesuvius where "he saw enough to be convinced that both were the products of the gradual accumulation of lava flows."[42] In Sicily, he explored the region around Etna:

> "Lyell studied the rocks exposed in the surrounding cliffs, which offered natural sections through the volcano. Although confused at first by some very confusing appearances, he convinced himself that they did indeed show that Etna, like

Vesuvius, had accumulated layer by layer by the addition of successive lava flows running down its flanks. This confirmed that the whole volcano had grown in the same manner as had been documented in the centuries covered by human records, which suggested in turn that its total age must be vast beyond human reckoning."[43]

Lyell completed his tour and returned to England, where he quickly finished the first volume of *Principles of Geology*, which was released in 1830.

Discussion

By the time of Lyell's *Principles*, geologists were convinced that volcanoes and volcanic terrains were concrete evidence of prehistory. However, their arguments were flawed, typically by unwarranted extrapolation from limited evidence. Logical errors arose from an inability to differentiate between assumptions and data, and gradualism was a major presuppositional error. Although Lyell is credited with this doctrine, it was common to many naturalists, including Scrope, Soulavie, Montlosier, Desmarest, and Hamilton. All were convinced by the scale of observed flows from Etna and Vesuvius that vast ages were needed to build those cones. Gradualism was implicit. None considered changing rates through time.

The paucity of actual evidence gave free rein to subjectivity, leading to absurd errors, such as Hamilton's dismissal of biblical history based on the presence of volcanic rock beneath Pompeii and Herculaneum. Valid explanations of that rock were certainly possible within biblical time, but were never considered. Modern knowledge of volcanoes and volcanism clarifies the errors of these early volcanologists.

Ironically, it is geological actualism that militates against their argument. Observations of modern volcanoes and their ancient products argue against their conclusions. The most common argument for time was based on the scale of flows they observed—a few eruptions of Vesuvius and Etna. Modern eruptions and flows demonstrate great variety in the strength of eruptions and the volume of material ejected (figures 9 and 10). For comparison sake, I made a rough calculation of the volumes of the both Vesuvius and Etna. For the former, using a base radius of 9 km, a cone 700 m across, and a height of 1,281 m, Vesuvius is roughly 118 km^3. Etna, with a 140-km circumference and a height of 3,329 m, yields a volume of 1,731 km^3. For comparison, the volume of Mt Kilauea, in Hawaii, is about 30,000 km^3.[45] Recent eruptions vary greatly in the amount of material ejected (figure 9). The total volume of Vesuvius is only 36 times the material released in the AD 79 eruption and significantly less than that released by Tambora. These modern observations alone invalidate the

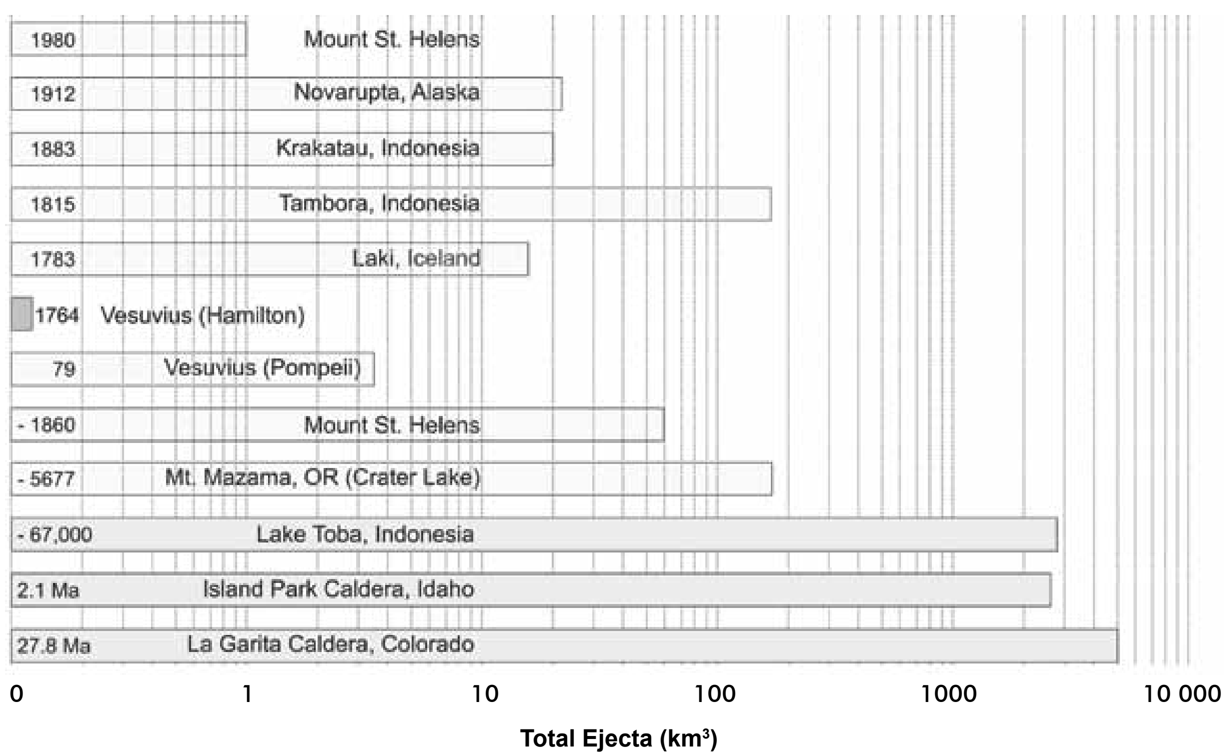

Figure 9. Comparative volume of ejecta from notable eruptions in cubic km. Note log scale. (To convert to cubic miles, multiply by 0.2399.) Note the 1764 eruption observed by Hamilton; three orders of magnitude less than Tambora and more than five orders of magnitude less than past 'supervolcanoes' (darker grey at bottom).[44]

argument for time by the early savants. Past eruptions, based on the extent of preserved ash and lava beds, were much greater—typical of the supervolcanoes at the bottom of figure 9. Compared to these, the 1764 eruption of Vesuvius studied by Hamilton was insignificant.

A common scale used to compare eruptions is the Volcanic Explosivity Index (VEI). Ranging from 0–8, it uses ejecta volume, chemistry, duration, and the height of the column into the atmosphere. The AD 79 eruption of Vesuvius rated a 5, and the 1815 Tambora eruption, a 7. No eruption dated to the past 10,000 years has been rated the maximum of 8.[46] Figure 10 rates recent major eruptions by this scale, showing the volume of lava and tephra released.

Not only were the savants wrong about the magnitude of modern eruptions, but they had not studied a sufficient number of historical examples to learn that ancient eruptions were often much larger than those shown in figures 9 and 10. This is perfectly consistent with biblical history; larger eruptions would be expected during the onset and mid-to-late-Flood tectonic reorganization of the crust to accommodate the receding waters.

Volcano	Location	Date	VEI	Lava (km^3)	Tephra (km^3)
Pinatubo	Phillipines	1991	6		11
Hudson Cerro	Chile	1991	5		4.3
El Chicon	Mexico	1982	5		2.3
St. Helens	Washington	1980	5	0.074	1.2
Agung	Indonesia	1963	5	0.1	1
Bezymianny	Kamchatka	1955	5		2.8
Cerro Azul	Chile	1932	5+		9.5
Novarupta	Alaska	1912	6	0.01	28
Santa Maria	Chile	1902	6		20
Krakatau	Indonesia	1883	6		20
Cosiguina	Nicaragua	1835	5		5.7
Tambora	Indonesia	1812	7		160
Long Island	New Guinea	1660	6		30
Huaynaputina	Peru	1600	6		30
Bardabunga	Iceland	1477	6	2.5	10
Quilotoa	Ecuador	1280	6		21
Changbaishan	China	1000	7		96
Ceburoco	Mexico	930	6		11
Churchill	Alaska	800	6		27
Ambryn	Vanuatu	50	6+		70
Santorini	Greece	1610 BC	7		99

Data courtesy of www.volcano.si.edu

Figure 10. Table showing some of the largest eruptions in human history. These vary significantly in size, and from those observed by the early savants. For example, the eruptions seen by Hamilton at Vesuvius were more than 2 orders of magnitude smaller than the AD 79 eruption.

Scientists have documented a number of 'super eruptions', including Toba, in Indonesia, which released nearly 3,000 km^3 of material, approximately twice the volume of Mt Etna.[47] An eruption at Fish Canyon in southwest Colorado, dated 28 million years ago, released about 5,000 km^3 of material.[48] The Yellowstone Caldera has been the site of three super eruptions, dated within the past 2 million years, each releasing more than 1,000 km^3.[49] All of these dwarf any historical eruption, most more than an order of magnitude greater than Tambora. In contrast, the 1764 eruption of Vesuvius documented by Hamilton released 0.01 km^3 of lava of 0.001 km^3 of tephra—five orders of magnitude smaller than the super eruptions.

But even super eruptions are dwarfed by the large igneous provinces (LIPs).[50,51] The Ontong Java Plateau is the largest documented LIP with an estimated volume of as much as 76 million km^3. The Deccan basalt flows are over 8 million km^3, and the well-known Columbia River Basalts are 1.3 million km^3.[52] Furthermore, almost all of the large LIPs formed rapidly. Geologists admit less than a total of 7 million years for the Ontong Java Plateau, with the bulk of the eruptions occurring in two phases; the first of approximately 500,000 years and the second of 3 million.[53] Even these numbers are deceptive. Analysis of the physical properties of lava flows at the Columbia River Basalts demonstrated that major individual flows, supposedly occurring over 11.2 million years, actually happened quite rapidly—in hours or days.[54]

Reed used physical data to constrain basalt flows at the North American Midcontinent Rift System.[55] The first time constraint is the time of ascent of the magma through the crust. Rates of up to 2 m/s have been documented for basalt flows, and even hydrous rhyolite has been shown to ascend at 1 m/s.[56] Even through thick continental crust, this translates into only a few hours. The next component is the actual eruption rate. The single most important factor is the size of the vent. It is estimated that 4-m-wide vents reaching 100 km in length would have erupted basalt at rates of 30,000 kg/sec/m length of the vent.[57] Reed estimated that the 1,000,000 km^3 of basalt at the Midcontinent Rift System could have been emplaced in forty days through one vent 10 m wide and 25 km long.[55] Of course, the documented vent system around the rift is much larger and so the actual time of emplacement could have been as little as a few days.

Geologists ignore these physical factors because they date the duration of flows radiometrically. Reed demonstrated that the results of this type of dating at the Midcontinent Rift System grossly overestimated the time of emplacement. It would not be surprising if the same errors are present in dating larger LIPs, like the Ontong Java Plateau. In any case, it is clear that the argument of the 18th and early 19th century savants, from Desmarest to Lyell, was wrong, being based on insufficient data. They assumed gradualism rather than demonstrating it. And their actualistic method invalidates their conclusions.

There are only two specific arguments that retain a shred of evidentiary value, though both are inconclusive. The first is Recupero's observation of multiple stacked flows at Mt Etna with weathered horizons. The second is the time needed for the present configuration of basalt flows, interbedded sediments, and eroded valleys at Auvergne, as argued forcefully by Scrope and Lyell.

The presence of multiple stacked flows *per se* is not an issue of time. Under Lake Superior, the thickest part of the Midcontinent Rift System, there are probably 500–750 individual flows, many stacked on each other.[55] Given the eruption rates, they would likely have formed within days. Recupero's argument, however, was based on the weathering of the tops of flows. Rudwick notes that the argument is bolstered by observed flows at Etna that had not begun to weather, even after a century.[58] However, the timing of weathering must not be too great; the region is known for its rich soils. The interpretation by Recupero and Brydone depended on several factors: (1) that the fossil soil horizons were really soils, (2) that weathering rates could be applied in a gradualist fashion, and (3) that conditions conducive to weathering were constant.

Woodmorappe and Oard[54] saw similar weathered horizons in some of the Columbia River Basalts. They noted that these horizons might be hydrothermal, not true paleosols. Investigation of these flows at Mt Etna would be an interesting research project, but the Recupero interpretation remains one of several explanations. Klevberg *et al.* noted that paleosols are frequently misidentified in the rock record.[59] The argument from Auvergne, advanced by a number of naturalists, but most forcefully by Scrope and Lyell, was that the flows, sediments, and erosion demanded long ages of time. Reed[2] has shown that the argument from valley erosion is flawed, and sedimentary units with interbedded basalt flows are common features throughout the rock record. The length of time required for their emplacement is primarily a function of volcanic and hydraulic properties, not time.

Conclusion

The second major argument for deep time in the early days of geology was that the rate of accumulation of volcanoes from observed eruptions was too slow to accommodate the biblical timeframe. That argument is falsified by observation; both of modern eruptions and of the physical parameters of ancient eruptions and LIPs. Hamilton's argument from volcanic rocks beneath Pompeii is absurd on its face, although it does serve to illustrate the bias of the Enlightenment intellectuals. The argument that the terrain of Auvergne demanded great time depends on the assumption of gradualism, which has since been rejected by many secular geologists. Recupero's argument of weathered flow surfaces at Mt Etna was the only feasible argument made, but is inconclusive based on the possibility of the 'weathered' surfaces being caused by contemporaneous hydrothermal processes.

Ironically, the actualistic method advocated by these savants is the basis for invalidating their conclusions about deep time. Nearly two centuries of observation since Lyell have brought out new knowledge of eruptions and volcanism, showing scales dwarfing the small flows at Etna and Vesuvius. Furthermore, solid empirical data document the much larger scale of volcanism in the past; another case of actualism contradicting Lyell's steady-state vision of earth history.

Of the three major arguments for deep time advanced in the crucial years of the late 1700s, the first two—time needed for valley erosion and time needed to accrete volcanoes and volcanic terrains—have failed. The final argument is the time needed to accumulate the sedimentary rock record, and that will be the topic of the final paper in this series. If it is also false, then prehistory and its timescale will be shown to be something other than empirical conclusions; they are either beliefs stemming from Enlightenment secularism or the products of circular reasoning.

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