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Faith in floods: Field and theory in landscape evolution before geomorphology

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ABSTRACT

Opinions about the origin of topography have long marked the frontier between science and religion. The creation of the world we know is central to religious and secular world views; and until recently the power to shape landscapes lay beyond the reach of mortals, inviting speculation as to a role for divine intervention. For centuries, Christians framed rational inquiry into the origin of topography around theories for how Noah's Flood shaped mountains and carved valleys. Only as geologists learned how to decipher Earth history and read the signature of Earth surface processes did naturalists come to understand the forces that shaped the world. In this sense, the historical roots of geomorphology lie in the tension between faith in theories and the compelling power of field observations—issues that remain relevant to the practice of geomorphology today.

1. Introduction

Theories color how people interpret observations, and field observations shaped theories of landscape evolution long before the development of geomorphology as a distinct discipline (Chorley et al., 1964; Davies, 1969; Montgomery, 2012). Whereas scientists no longer argue about the physiographic expression of Noah's Flood, the fundamental problems that arise from prioritizing theories over field observation—of elevating belief over data—remain pertinent today. Recognizing the historical tension between field and theory helps frame their complementary nature. In this sense, a brief and by no means comprehensive review of early thinking about landscape evolution and the search for geomorphological evidence of a global flood can provide historical context for appreciating the symbiotic relationship between and cross-pollination of fieldwork and theory.

2. Classical Greeks

Classical Greek philosophers and geographers recognized that landscapes evolved over long time frames in response to changes in erosional processes and human influences. Some of their views parallel modern conceptions, whereas others seem appropriately dated today. In either case, their theories tended to be rooted in attempts to explain field observations.

In the sixth century B.C., the Greek philosopher Xenophanes found layers of shells entombed in rock at Malta and casts of fish and seals in the stone quarries of Syracuse (Mayor, 2000). He concluded that evaporation of a great sea stranded marine animals in mud that dried into rock. He then theorized that life was repeatedly destroyed and generated anew through grand cycles in which the sea and land gradually changed places.

Around the same time, the Greek philosopher Thales and his students held water to be the most basic form of matter. They considered the surface of Earth a crust that had hardened over a primitive ocean. Earthquakes arose from the shifting of this thin shell of land covering a vast subterranean sea. Two thousand years later, this notion would resurface in seventeenth century attempts to explain the source of all the water needed to produce a global flood.

Classical Greeks also recognized that landscapes evolved over long time spans (Mayor, 2000). Around 430 B.C., Herodotus noted how deposition of silt carried by the Nile gradually pushed Egypt seaward, stranding the shells of marine creatures far from the coast. The striking contrast between the rich, black alluvial soil of the Nile delta and the bare rocky soil of Libya and Syria showed how the Nile left its gift of rich delta soil as Egypt advanced out into the Mediterranean.

The renowned philosopher Aristotle (384–322 B.C.) took such thinking a step further and proposed that the land and sea slowly swap places (Mayor, 2000). Silt and sand carried by rivers gradually fill the sea, which eventually rises to inundate neighboring land. Conversely, fossils testified to how sea became land. An eternal cycle in which land became sea and then land again aligned with his conception of a world without beginning or end. Aristotle thought this happened so gradually as to escape observation. Civilizations rose and fell before they could record even a single round of this grand cycle.

3. Augustine to Leonardo

Early Christian concepts of landscape evolution centered around the biblical stories of the Creation and Noah's Flood, the only events mentioned in the Bible that could have shaped landscapes. Some early biblical commentators argued that Genesis clearly indicated

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that mountains already existed where it stated that Noah's Flood covered all the high hills under heaven. They interpreted this to mean that mountains could not have been made during the Flood and, therefore, must have been formed at the Creation—the only other significant event in Earth history mentioned in the Bible. Other biblical expositors eager to seize on negative as well as positive evidence questioned why mountains were not mentioned earlier if they had existed before the Flood. Yet others suggested that the initially subdued topography of the world only rose into mountains as a result of the Flood. Despite disagreements over the origin of topography, biblical commentators generally agreed that the surface of Earth had been slowly eroding away since the Flood. Landscape evolution was thought to have involved the initial creation and subsequent remodeling during Noah's Flood. Differences of opinion centered on how the flood came about, where all the water came from, and where it all went afterward.

Even in the earliest days of Christianity, major theologians professed faith in the ability of investigations of the natural world to reveal Earth history (e.g., Augustine, 1982). In the fourth century A.D., St. Augustine cautioned against discounting reason in interpreting the Bible. For why, he asked, should people accept a religion that taught things at odds with what they knew from reason and their own experience? Augustine argued that reason should guide the search for knowledge about the natural world, such as debates over how to interpret the origin of the world and its topography.

> *It is a laborious and difficult task for the powers of our human understanding to see clearly the meaning of the sacred writer in the matter of these six days. … If we are able to make any effort towards an understanding of the meaning of those days, we ought not to rush forward with an ill-considered opinion, as if no other reasonable and plausible interpretation could be offered* (Augustine, 1982, pp. 103, 135).

Augustine considered fossils entombed in the rocks that made up mountains as compelling proof of a global flood. He also theorized that flat, antediluvian topography helped explain how Noah's Flood submerged the whole world.

> *It is highly probable that in the early days of the earth most, but not all, areas were flat, so that there could be wider dispersion and expansion of the waters as they broke forth* (Nicolson, 1997, p. 90).

Given that he based his arguments on reason, it seems unlikely that Augustine would have rejected modern geology in favor of a literal reading of Noah's Flood as a globe-wrecking deluge.

Augustine's contemporaries, like Procopius of Gaza (c. A.D. 465–c. 538), also considered fossils to be persuasive evidence of a global flood:

> *It can be shown clearly in many other ways that a universal flood came upon the earth … . For even today in mountains that are lofty and difficult to climb marine remains are found…* (Young, 1995, p. 26).

The accepted theory of a global flood provided what seemed to be a reasonable explanation for the otherwise perplexing problems of fossils and the formation of topography.

The power of erosion to shape the land was recognized by some early observers, but the short amount of time believed to encompass Earth history limited the amount of work that processes operating today were thought capable of accomplishing. For example, in the seventh century A.D., Saint Bede (the Venerable Bede) argued that Noah's Flood annihilated the original Earth and reshaped topography (Nicolson, 1997).

> *The earth took on a different appearance as the waters receded. It is believed that some mountains and valleys were originally created but not to the extent that they are now found on the earth's surface. It might be possible to deny this if it were not for the fact that we are able to observe changes every year brought about on the earth by the action of water. Thus it is all the more credible that such changes took place at that time, when the action of the waters attacking the earth was more powerful and of longer duration* (Nicolson, 1997, p. 91).

Bede applied geomorphic reasoning in deducing that if modern rivers could gradually modify topography, then a cataclysmic disaster like Noah's Flood could rapidly carve valleys and shape mountains.

The Islamic scholar Avicenna (A.D. 980–1037), also known as Ibn-Sina, thought that mountains could form by either uplift from earthquakes or from erosion by running water over long periods of time. Avicenna wrote about the layered rocks of his native Uzbekistan, noting that succeeding layers were gradually deposited one atop another. The first translation of his text into Latin was missing this key passage, although it is unclear as to whether this reflected deliberate censorship or transcription from an incomplete copy. That Avicenna's book initially was thought to be a long lost work of Aristotle, whose belief in the eternity of the world was considered heretical, did not help acceptance of the idea that rocks were built up slowly from the settling of individual layers on the sea floor.

Medieval universities provided neither protection for nor encouragement of creative thinking. They were not established to discover things but to preserve classical knowledge. Respectable academics absorbed the knowledge of Aristotle and his contemporaries. Learning about the world became so focused on gleaning tidbits from Classical works that the sixteenth-century Danish alchemist Petrus Severinus advised his students to go outside and see things for themselves.

> *Burn your books and buy stout shoes, climb the mountains, search the valleys… and the deep recesses of the earth … Observe and experiment without ceasing, for in this way and no other will you arrive at a knowledge of the true nature of things* (Cutler, 2003, p. 17).

As understanding of the natural world grew, figuring out how to generate all the water necessary to submerge the world and trigger the biblical flood became increasingly challenging.

Leonardo da Vinci (A.D. 1452–1519) noticed things about the shells of marine creatures entombed in the rock beneath his hometown of Vinci that made him doubt Noah's Flood left them in the rocks (Mather and Mason, 1970). Some shells were clamped shut, as if buried alive. Others were broken into fragments and scattered in deposits resembling modern beaches. Pages of layered rock even preserved worm tracks. How, he wondered, could worms have been crawling around in the middle of a catastrophic flood?

Watching how flowing water moved sediment, Leonardo concluded that a great flood could not have carried ancient seashells up into the mountains for a simple reason: fossils and other objects heavier than water sank to the bottom of a current. Noah's Flood could not have parked fossils high in the mountains *because things which are heavier than water do not float high in the water* (Mather and Mason, 1970, p. 5). Also he recognized that the water at the bottom of a wave moves away from shore; the flood should have moved fossils out to sea rather than pushing them onto the highest peaks. In his notebooks, Leonardo mocked the idea that the biblical flood stranded marine creatures far above the sea. This just did not square with the way the world worked. Earth history was more complicated than implied by a simple reading of Genesis.

Leonardo reasoned that layers of sedimentary rock formed as mud gradually settled to the bottom of an ancient sea. Fossil shells preserved in the rocks high on ridges around Florence were deposited during an era of higher sea level. Seeing no evidence of a catastrophic deluge, he concluded that rivers and streams cut the valleys of the Arno basin. Leonardo also noted how streams were muddier where they flowed through populated areas.

Leonardo was not alone in questioning whether the Flood sculpted topography and in seeing the ability of erosion to shape the land. German scholar Georg Bauer (A.D. 1494–1555), better known as Agricola (the grandfather of mineralogy), wrote of the power of rivers and streams to carve landscapes (Mather and Mason, 1970). He saw mountains as the work of erosion.

> *Now we can plainly see that a great abundance of water produces mountains, for the torrents first of all wash out the soft earth, next carry away the harder earth, and then roll down the rocks, and thus in a few years they excavate the plains or slopes to a considerable depth; this may be noticed in mountainous regions even by unskilled observers. By a similar process the impetus of water entirely overthrows and flattens out hills and mountains* (Agricola, 1912, p. 595).

Well acquainted with mountainous terrain through his experience as a physician in mining communities, Agricola argued that anyone could see how wind, rain, and floods gradually shaped the land.

> *All these varied and wonderful processes by which water destroying builds and building destroys, mightily altering the appearance of the earth's surface, have been in operation since the most remote antiquity, so far beyond the memory of man that none can tell when they had their beginning* (Nicolson, 1997, p. 155).

In anticipating the concept of geologic time, Agricola recognized how geomorphological changes happened so slowly as to prevent directly observing the creative work of nature.

Leonardo and Agricola may not have been alone in endorsing the power of erosion to shape the land, but they were in the minority. Noah's flood remained the dominant theory of landscape evolution through the seventeenth century.

4. Seventeenth century savants

At the start of the seventeenth century A.D., two schools of thought framed views about the nature of Noah's Flood. One camp imagined a violent current that swept across the world, shattering nature's the crust of Earth and carving the topography. The other described the biblical flood as gently smothering all life but leaving the surface of Earth unscathed.

Imprisoned for over a decade on the charge of being an agent of Spain, Sir Walter Raleigh (c.1552–1618) wrote his history of the world since the Creation while awaiting execution (Raleigh, 1628). Raleigh marshaled arguments in support of the biblical account of a global flood, noting that Native American soothsayers told him of a great flood that long ago covered their land. To explain where all the water for the Flood came from, he argued that the atmosphere condensed all at once and then combined with water that welled up from the interior of Earth to sweep away corrupt societies. Raleigh's attempt to explain the biblical flood influenced generations of natural philosophers seeking to understand the origins of topography.

But Raleigh himself rejected the idea of a violent flood. He argued for tranquil inundation. How, he wondered, could the Flood have reshaped topography when Moses described the Garden of Eden in terms of modern geography? And did not the olive leaf that the dove brought back to the ark mean that the flood did not even rip up vegetation? So how could it have stripped away the underlying ground, let alone carve deep valleys into lofty mountains? Raleigh dismissed the idea of a local flood because he thought that enough water to cover even the highest mountains lay stored below ground. With the radius of Earth more than a hundred times the height of the tallest mountains, drowning the world simply required unleashing the fountains of the deep. Where did Raleigh get this idea?

Aristotle had taught that subterranean reservoirs supplied the springs that fed runoff to rivers and streams through a terrestrial plumbing system that acted like a giant wick soaking up the oceans. Raleigh believed the huge subterranean lakes, thought to lie beneath mountains, were the source of the biblical flood. These great reservoirs, known as *hydrophylacia*, were theorized to account for the observation that rivers continued to flow long after rain stopped—virtually all year long in most of Europe. Where else could year-round flow come from if not some underground source that nourished mountain springs?

Many seventeenth century natural philosophers indulged in theoretical speculation untethered from field observations or evidence. Today, their fantastic theories serve as reminders to keep interpretations of field data unbiased by theories and of the need to constrain theories with observations. The great philosopher Descartes proposed that mountains formed when the primitive surface of the planet collapsed into an inner sea trapped between the outer crust and a metal-rich inner crust. Unencumbered by field studies, highly imaginative theories proliferated to explain the origin of topography. Most ascribed a key geomorphic role to the biblical flood. The first use of geology in English was the title to a 17th century book about Noah's Flood (Warren, 1690).

The Cambridge cleric Thomas Burnet elaborated on Descartes' model in his *Sacred Theory of the Earth* (1684) to explain what he saw as evidence of a grand catastrophe in the chaotically convoluted and deformed rocks of the Alps. He interpreted distorted strata and rugged topography as the collapsed ruins of a once perfect Eden. Burnet proposed that at Creation God commanded the elements to sort by density, the heaviest elements sinking to the center to the core of Earth and the lighter elements coalescing into a thin crust above a subterranean sea (Fig. 1). The heat of the Sun gradually warmed and cracked the outer crust, which eventually collapsed into the watery abyss, triggering Noah's Flood and leaving behind mountains as the floodwaters drained away. Burnet offered the seasons as further evidence of this catastrophe, arguing that before the deluge Earth stood upright around its rotational pole and basked in perpetual equinox. Burnet theorized that the force of the biblical flood threw the planet off its axis, creating the seasons.

He inferred that catastrophic floods affected not only Earth, but that similar floods had affected most of the other planets. The rings of Saturn were the equatorial remnant of an outer crust that broke apart leaving a narrow strip intact. Only Jupiter remained in its primitive smooth state. His theory of an enormous flood colored how he viewed evidence on this world and others.

At the end of the seventeenth century, Gresham College medical professor John Woodward elaborated on Burnet's sacred theory and proposed a mechanism for how Noah's Flood emplaced fossils in rocks and shaped the world in his *Essay Toward a Natural History of the Earth* (1723/1695). Woodward adjusted Burnet's idea of gravitational sorting of the primordial crust of Earth and applied it to settling of the material ripped up by Noah's Flood. He proposed that God triggered the Flood by temporarily suspending gravity, which caused the world to disaggregate. When God turned gravity back on, everything settled out by density, forming layered rocks. Topography formed from the localized collapse of the newly disturbed surface of the planet.

Woodward thought that fossils were preserved in rocks because organic fibers held plant and animal tissue together. He dismissed the idea that problematic discoveries of fossils of unknown species was a problem at all, confident that living examples of everything found in the rock record would eventually be found in some remote region or deep in the sea. Compiling accounts from correspondents around the world describing fossils entombed in rock, right to the top of the highest mountains, Woodward concluded that fossils and rocks were mixed up by some kind of grand catastrophe that affected the world far beyond Britain. How, he asked, could one explain such field observations other than by a global flood?

Problems with Woodward's elegantly simple everything-settled-out-after-the-flood idea became obvious as naturalists investigated the stratigraphy of their own regions. In a description of a Staffordshire coal pit in

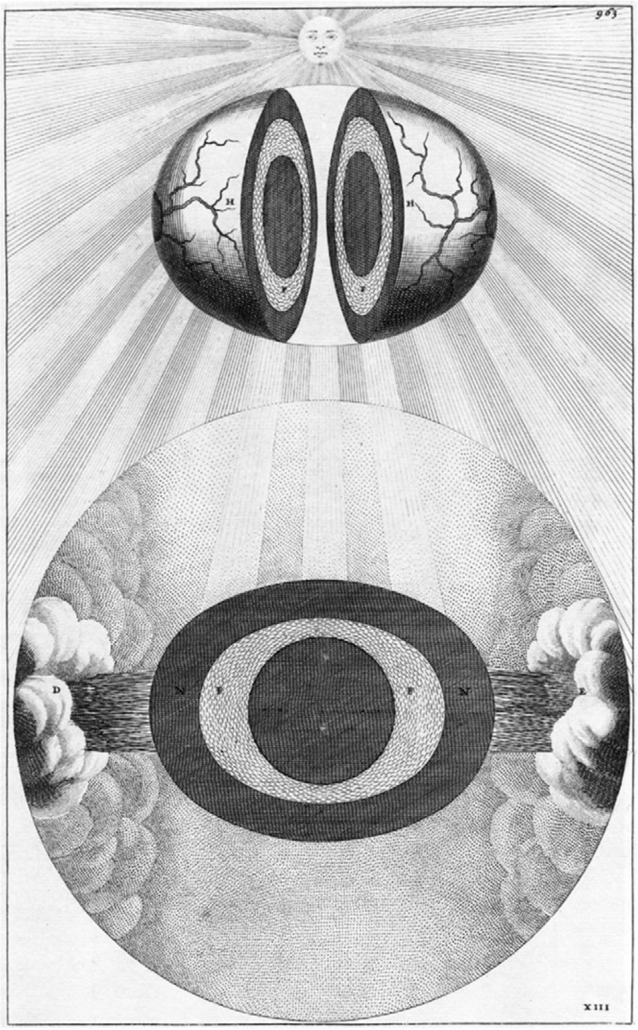

Fig. 1. Illustration of Thomas Burnet's theory to explain Noah's Flood through the original make up of Earth as a sphere with an outer crust solidified above an inner sea (scaly pattern). When the heat of the Sun cracked the outer crust (upper panel) the out crust foundered into the inner sea, combining with water rained out from a collapsing vapor canopy to flood the world, from Goeree (1690).

the *Philosophical Transactions of the Royal Society of London,* Fettiplace Bellers (1710) included a table of specific gravities of strata as evidence refuting Woodward's model. Out in the field, denser stuff did not always lie beneath lighter stuff. The rocks themselves dismissed Woodward's globe-dissolving deluge.

Steno (1638–1686), the Catholic bishop revered as the grandfather of geology, developed his famous principles to interpret geological field evidence (e.g., Cutler, 2003). As he became enamored with geological problems after ascertaining the organic origin of fossils, Steno began observing the relationship between geology and topography on long fossil collecting hikes in the Tuscan mountains. He was starting down a new path. His training in anatomy was in an established field, with established methods and theories to support or challenge. Geology was another thing altogether. Indulging Steno's curiosity, his employer Ferdinand II, Grand Duke of Tuscany, opened quarries and mines so that Steno could explore what lay underground. The more Steno saw the more he became convinced that fossil-bearing rocks were laid down in an ancient sea.

Steno mapped the story he read in the rocks onto his understanding of biblical stories. To explain Tuscan geologic history he invoked two three-stage cycles of flooding, drainage, and buckling of the land (Fig. 2). In the first stage of each cycle, water-laid sediments left behind a succession of horizontal layers. Then, after the water receded the sediments hardened into rock, the action of water or fire within Earth carved out great subterranean caverns. Collapse of the overlying layers into these caverns produced the tilted strata now seen at the surface. In the second of these cycles, only the valleys received sediments. Then, the landscape we know today formed once the waters receded, producing another round of undermining and collapse.

Steno's greatest insight was that the present arrangement of the layers that make up our world can be used to read its history. The key to reading Tuscan geology was the simple idea that younger rocks lay on top of older ones. Steno adopted this idea, which remains the basis for modern geology, to help explain how Noah's Flood shaped the Italian landscape.

Noah's Flood remained the central theory for thinking about landscape evolution until well into the eighteenth century. After all, what better theory could explain marine creatures trapped in rocks found high in the mountains, or large fossils though to be sinners drowned in the Flood (Fig. 3)? That began to change as field investigations of European stratigraphy revealed a longer and more complicated story to Earth history than previously imagined by all but a few.

5. Finding time enough

About the time that Burnet and Woodward were proposing their deluge-driven theories of Earth history, French diplomat Benoit de Maillet (1656–1738) traveled through the Middle East and around the Mediterranean as French consul in Egypt (de Maillet, 1797). His field observations of the rocks in the region convinced him they had been deposited during a gradual lowering of the oceans drawn out over many millions of years. He thought that this original universal ocean gradually shrank, stranding marine sediments and seashells high and dry in the mountains.

Written as if based on Egyptian legends, de Maillet's book (1797) proposed that the world was about two billion years old—how long he thought it would take a primeval, globe-covering ocean to seep down into cracks and fissures. This was way out of bounds for the time allowed by biblical chronology and left no geologic role for Noah's Flood. He also claimed that people arose from mermaids and mermen. To contemporaries, his outrageous claim of an unimaginably

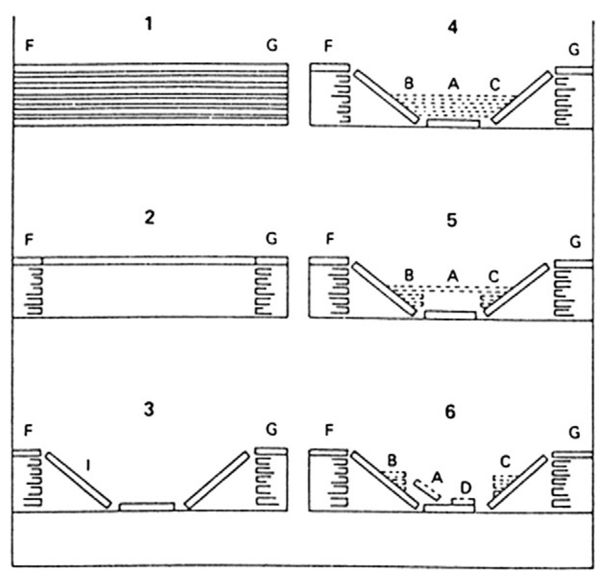

Fig. 2. Illustration of Steno's six-stage model for the development of the landscape around Florence: (1) fossil-free sedimentary rocks precipitate in a universal ocean; (2) fire or water excavate subterranean caverns; (3) continents collapse, inundating newly formed valleys in a great flood (Noah's Flood); (4) layered sedimentary rocks containing fossils deposit as floodwaters recede; (5) renewed undermining of younger rocks in valleys lead to (6) a final round of collapse that creates modern topography.

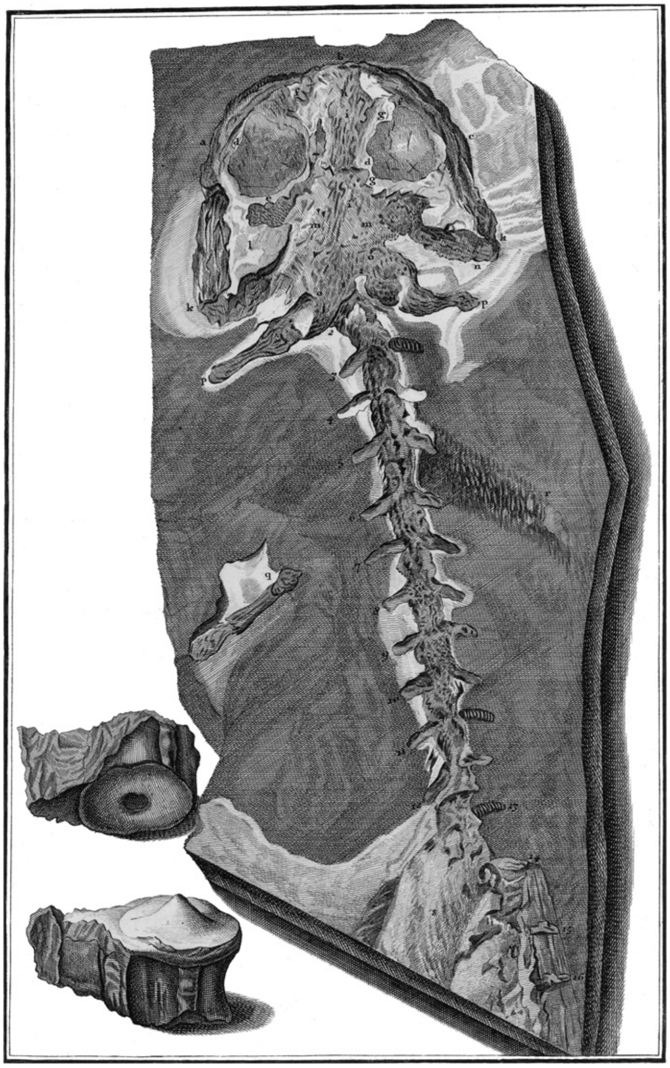

Fig. 3. *Homo Diluvii Testis* (Man Who Testifies to the Flood), the giant fossil amphibian initially thought to represent a sinner drowned in Noah's Flood, from Scheuchzer (1731).

ancient Earth probably seemed like just another bizarre idea. Aware that his theory would prove controversial, Maillet dodged censure by attributing his argument to an Indian philosopher Telliamed (de Maillet spelled backwards)—and delaying publication until a decade after his own death.

Baron Georges-Louis Leclerc, Comte de Buffon (1707–1788) and director of the botanical gardens in Paris, wrapped de Maillet's shrinking ocean into a grand theory to explain biologic and geologic history as Earth gradually cooled from a molten fireball. In the first volume of his massive, 34 volume *Histoire Naturelle* (Buffon, 1749), Buffon argued that the planet formed when a comet knocked off a piece of the sun. After the molten blob cooled into a rocky satellite, a universal ocean receded to expose the continents.

Two years later the theological faculty of the Sorbonne sent Buffon a letter identifying in it more than a dozen heretical ideas, including that currents in the waters of the primeval ocean shaped mountains and valleys—that topography was made by erosion rather than by God himself at the Creation or through Noah's Flood—and that eventually erosion would deliver the mountains to the sea, reducing the land to a level plain. Forced to choose between recanting and keeping his prestigious position, Buffon renounced everything in his book *respecting the formation of the earth, and in general all which may be contrary to the narrative of Moses* (White, 1910, p. 215).

Buffon nonetheless kept experimenting with how long it took to cool molten metals and determined that the first day of creation would have had to last more than 25,000 years for the planet to cool to the point where water could settle on it. Based on rainfall rates, he calculated that the biblical second day of creation must have lasted 10,000 years to build up the primordial seas as atmospheric waters rained down. Decades later, when Buffon estimated the age of Earth as about 75,000 years old (Buffon, 1778), the church remained silent, torn by internal controversy over how to interpret Genesis.

Buffon developed the argument that the days of creation corresponded to geological ages (Buffon, 1778). Cautiously refraining from publishing an estimate that Earth was actually millions of years old, he argued that the planet gradually cooled to form the world we know today. The first of his great epochs saw the formation of Earth and other planets. During the second epoch, the rocky interior of Earth consolidated and released volatile substances to create the atmosphere. During the third, about 35,000 years after the planet formed, water covered the continents leaving behind marble, stratified rocks, coal, and marine fossils. Rushing currents on the bottom of this great sea carved modern topography. Volcanoes became active in the fourth epoch. Elephants and other tropical animals inhabited Siberia during the fifth epoch when the northern regions of the globe enjoyed a more southerly climate. In Buffon's sixth epoch, the modern continents became separated from each other as the intervening land subsided to form ocean basins. Finally, the arrival of mankind ushered in the current epoch about 6000 years ago.

Eighteenth-century field studies of the European Alps began to document the regular order to European rock formations and undermined the view that topography formed in a single grand catastrophe. In 1721, University of Padua professor Antonio Vallisnieri concluded that far longer than Noah's Flood was needed to form the innumerable layers of marine rock in the Alps (Fig. 4). Thousands upon thousands of individual layers could not possibly have settled out in a single flood. He asked, how could simple settling produce hundreds of distinct layers of alternating composition and grain size for each day of the biblical flood? Not enough time was available for that many layers to settle out in a single year.

Catholic priest and naturalist Anton-Lazarro Moro followed Steno's description of mountains as either primary or secondary features depending on whether they consisted of massive or stratified (layered) rocks. He attributed the formation of unstratified, hard crystalline rocks, like granite and basalt, to the internal heat of Earth; whereas stratified rocks (like sandstone and coal) were laid down by water, reworked from erosion of primary rocks.

Venetian mining professor Giovanni Arduino expanded geologic classification to include four categories (Bates, 1950). The primary strata at the bottom of the geologic pile were tilted and lacked fossils. The overlying secondary strata were also tilted but contained fossils. The tertiary strata were fossil-bearing rocks made of gravel, sand, and clay derived from the underlying primary and secondary rocks. On top of all this was a fourth, or quaternary, level of surficial material recently eroded off the mountains by running water, like the sand and gravel of the Po Valley. Arduino claimed that his four divisions represented distinct epochs in Earth history. In short order, others found Moro's classification also worked in other mountain ranges, like the Apennines and Caucasus. The geologic story was more complicated than a single event, no matter how grand a catastrophe. Field evidence was starting to reshape views of Earth history and the relationship between topography and the underlying rocks.

One of the last serious attempts to explain all of Earth history and the formation of topography through Noah's Flood was Bristol clergyman and schoolmaster Alexander Catcott's (1725–1779) *Treatise on the Deluge* (1761). Catcott loved to geologize in the countryside of southern England where the discontinuous nature of the matching strata exposed on neighboring hills showed that something had removed a lot of rock.

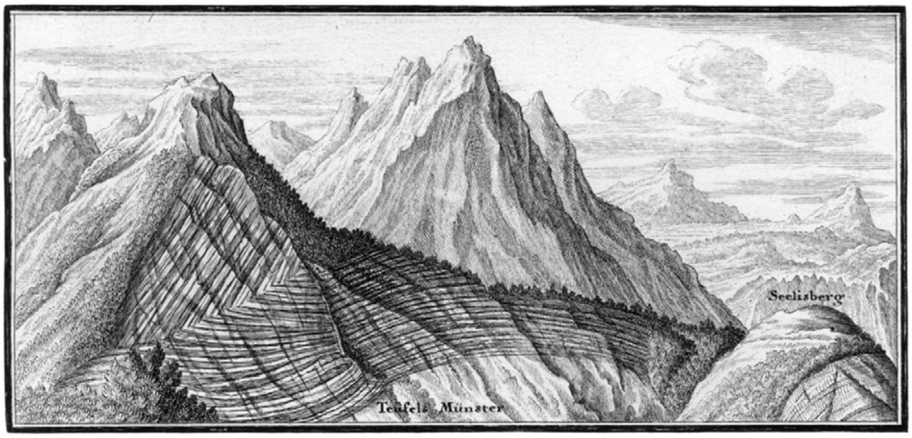

Fig. 4. Illustration of rock layers and internal structure of the Alps, from Scheuchzer (1731).

If a person was to view the naked ends or broken edges of the strata in a mountain on one side of the valley and compare them with their corresponding ends in the mountain on the other side of the valley, he would manifestly perceive that the space between each was once filled up, and the strata continued from mountain to mountain (Catcott, 1761, p. 163).

Catcott recognized that topography was carved out from once-continuous formations. It did not just result from collapse of the crust, as Burnet (1684) and Woodward (1723/1695) had theorized.

What gouged out all that missing rock? Earthquakes did not seem a likely candidate. But erosion by raging floodwaters did. Catcott saw the signature of the biblical flood as eloquently written in the form of the land.

Citing examples of Greek, Roman, and Native American flood stories as evidence of a global flood, Catcott merged Burnet's idea of flooding from a subterranean abyss with Woodward's idea that fossil-bearing rocks settled out from the floodwaters. Catcott proposed that the early Earth was hollow and filled with pressurized air, like a giant balloon. The outer crust was surrounded on both sides by water held in place by air pressure. When the heat from the Sun caused the interior air to expand and crack the crust, water rushed down to fill the hollow center and carved valleys into the formerly smooth surface. Then when the time came, all God had to do was pump up the pressure on the remaining air in the hollow center of the planet to push the water back up and out to generate the Flood.

Like Woodward, Catcott held that Noah's Flood dissolved the surface of Earth. He went on to argue that the receding floodwaters carved valleys into layered stacks of not-yet hardened sediments. Catcott's imaginative theory addressed the difference between the stratified and broken primary rocks and the younger fossil-bearing rocks he attributed to a global flood.

To test his theory Catcott took a large glass vessel and bored holes in its sides. After corking the holes, he filled the vessel with water and sequentially added pulverized stone, coal, clay, and chalk, letting each layer settle to form a stack of strata. When he pulled out all the corks the rapidly draining water carved miniature landscapes with tiny mountains, valleys, and plains. Ironically, Catcott's use of experimental methods introduced a modern scientific approach in support of ideas nearing their expiration date.

A naturalist who made careful observations of the relationships among landforms, surficial deposits, fossils and the strata containing them, Catcott remained puzzled by rocks composed of rounded pebbles that were themselves made of limestone or shale. A global flood could not explain sedimentary rocks contained within sedimentary rock. For how could supposedly soft sediments deposited by the Flood be solidified, ripped up, rounded into pebbles, and then incorporated into a younger deposit all during a single event? Had Catcott recognized this as the signature of two rounds of mountain building and erosion, he would have discovered geologic time and be hailed today as an influential scientific pioneer. Instead, his story offers a cautionary tale of the hazards of placing too much faith in an ill-conceived theory.

Scottish farmer James Hutton (1726–1797) developed the idea that landscapes are shaped by erosional processes observable today. Based in part on comparing the sandy soil that washed off his fields to the sandstone composing the stone fences surrounding them, Hutton proposed that material eroded from the continents slowly piled up in the sea until the pile got thick enough to melt its own base, causing the layers to rise back to the surface. His discovery of an angular unconformity between two sandstones—one Devonian and the other Silurian in age—later showed that geologic time consisted of time enough to raise and erode two mountain ranges and hide the rocky bones beneath the modern landscape (Fig. 5). His new theory was not immediately popular. It ran against the dominant perception that Earth history was geologically short and that topography was shaped by grand catastrophes or currents beneath a primordial sea. Hutton's ideas only caught on decades after his death, well after his friend and colleague John Playfair elaborated on them and, in turn, greatly influenced Charles Lyell, who championed and popularized the view that processes observable today are responsible for shaping landforms.

Swiss geologist Jean-André de Luc (1727–1817) was a leading proponent of reinterpreting Genesis to accommodate the increasing age of Earth. His *Letters on the Physical History of the Earth* (De Luc, 1831-1798) endorsed the idea that Earth history involved six epochs corresponding to the six days of creation. Convinced that rocks and landforms faithfully recorded Earth history, de Luc climbed mountains and descended into mines across Europe and based his opinions on detailed descriptions of strata after carefully summarizing and discussing the previous work of others. De Luc saw that the geology of Europe *demonstrated the conformity of geological monuments with the sublime account of that series of operations which took place during the Six Days, as periods of time, recorded by the inspired penman* (Cohn, 1996, p. 110). De Luc was impressed that even though Moses knew no physics or geology, the rock record paralleled Genesis—if interpreted as consisting of six ages rather than six days.

Convinced that Noah's Flood produced modern topography, de Luc set about showing it, confident that the rocks would back up the story. He understood the six days of Creation were of indeterminate length and that rocks and the fossils they contained formed in the early epochs of Earth history. People only arrived in the most recent epoch—the one ended by Noah's Flood.

De Luc thought continents were much larger before the Flood and that volcanic eruptions beneath the seabed and water slowly filtering down into the crust had carved out great caverns in the primeval

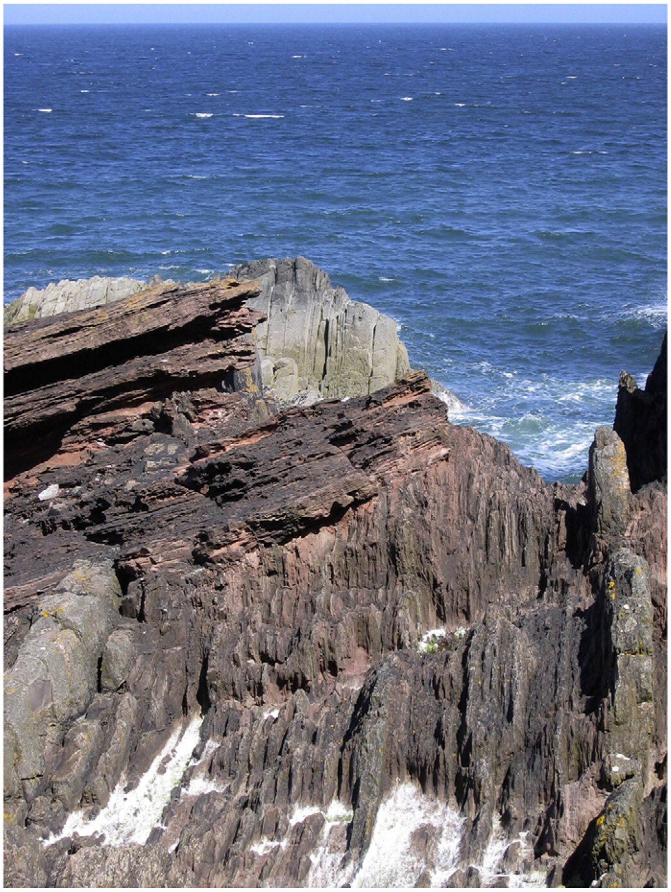

Fig. 5. Siccar Point, Scotland, where James Hutton recognized the immense span of time represented by the unconformity between Devonian and Silurian sandstone. Photograph by the author.

Earth. Much as Thomas Burnet theorized a century before, De Luc thought the collapse of huge cavities into an internal ocean beneath the crust of the planet drowned the inhabitants of the world. The lack of human fossils resulted from the bones having sunk to the bottom of the new sea. Entombed deep in the great abyss, they would never be found. The newly exposed bed of the former higher elevation sea became the modern land surface, which explained the exposure of marine rocks and fossils well above sea level.

De Luc argued that some animals survived on mountaintop islands before the floodwaters drained into gaping holes left by the collapsing continents. Together with the beasts released from the ark, these survivors repopulated the world. The Flood altered the center of gravity of Earth enough that the planet tipped off the vertical, generating the seasons and imposing the present climate zones. As for why none of this was laid out in the Bible, de Luc maintained that Moses only wrote about the part of the Flood that Noah witnessed. The rocks filled in the rest of the story.

The widespread belief that natural revelations discovered through science provided proof of a benevolent God was spelled out in William Paley's influential *Natural Theology* (Paley, 1802). He adopted Aquinas' view that because the Bible and the book of nature shared the same author, scientific revelations that contradicted biblical interpretations should provide natural guidance for better interpreting scripture. Pope Pius VII soon endorsed viewing the six days of Creation as of indeterminate length rather than as a literal week of 24-hour days. A decade after publication of Paley's popular book, Robert Bakewell sought to reconcile the geological and biblical chronologies in his *Introduction to Geology* (Bakewell, 1813), the first geology textbook published in English, by arguing that the chronology described in Genesis began when the world became habitable by man.

Paley's disciples thought the geologic evidence demanded a catastrophe of biblical proportions. Summarizing such thinking in *The Testimony of Natural Theology to Christianity* (Gisborne, 1818), Thomas Gisborne argued that the necessity of a grand catastrophe in Earth history verified the biblical story. Surficial strata were broken up and displaced everywhere he looked or read about. Rocks of the secondary formations—those laid down in layered strata—lay broken and twisted virtually wherever a window existed into the internal structure. He concluded that the surface of Earth showed sure signs of a grand catastrophe.

Gisborne further asserted that valleys were incised by flowing water. That all streams drained to the level of the oceans showed that topography was carved by water running down to the sea rather than by raging currents beneath a primordial global ocean. That only a third of the globe was dry land, only a fraction of which provided habitat suitable for civilized man, showed Earth was but a ruin of what a wise and beneficent God would provide. Finally, if the world were still in a state of innocence, it would not be subject to earthquakes and volcanic eruptions. Earth was broken, a wrecked paradise. Something big had reshaped its surface.

6. Too many floods

The late eighteenth century discovery of extinctions and field evidence interpreted as recording numerous grand catastrophes finished off the theory that Noah's Flood was responsible for laying down sedimentary rocks. When Napoleon's army returned from what is now Belgium with trophies plundered from natural history collections, French vertebrate anatomist Georges Cuvier compared fossil mammoth teeth to the molars of modern Asian and African elephants. Mammoth teeth matched neither living species. Mammoths no longer roamed the world. Cuvier's discovery of extinctions rocked geological thinking about Noah's Flood, which could not explain extinctions when a pair of every living animal was supposedly saved on the ark.

Mapping the rocks of the Paris basin, Cuvier discovered that different rock formations had unique faunas. Different periods in Earth history had different plants and animals. The fauna in each formation appeared to have thrived for a while before being replaced in the transition to the time represented by the next, overlying rock formation. Every now and then a great catastrophe would wipe out an entire fauna, which would be replaced by an entirely new fauna. This presented a theological dilemma because now too many floods were identified.

Cuvier's view that the geologic record was one of periods of stability punctuated by cataclysmic catastrophes became known as *catastrophism*. Cuvier thought that geology was plagued by an abundance of theories chasing a dearth of facts. He stressed unraveling the history of Earth through observations of rocks and the fossils they contained. In his view, grand theories should emerge from field evidence rather than conjecture.

In the early nineteenth century, giant boulders that littered landscapes of northern Europe were considered compelling evidence of a global flood. George Greenough (1778–1855), the first president of the Geological Society of London, argued in his *Critical Examination of the First Principles of Geology* (Greenough, 1819) that because one could rule out the ability of the normal action of rivers and the sea to move giant rocks, a really big flood must have parked such rocks where they were found. Greenough further argued that this deluge affected all of Europe based on the widespread deposits of surficial sand and gravel generally acknowledged to represent the last big thing to happen geologically. Although Greenough thought he could tell the direction the flood flowed from the orientation of mountains and valleys, he could find no evidence that revealed its age. As for the cause, he favored astronomer Edmund Halley's idea of a comet or meteor passing close by, or perhaps even slamming into Earth.

Less than a decade and a half later, Greenough recanted his support for a global flood in an address to the Geological Society.

> *Some fourteen years ago, I advanced an opinion, founded altogether upon physical and geological consideration, that the entire earth had, at an unknown period … been covered by one general but temporary deluge. The opinion was not hastily formed. My reasoning rested on the facts which had then come before me. My acquaintance with physical and geological nature is now extended; and that more extended acquaintance would be entirely wasted upon me, if the opinions which it will no longer allow me to retain, it did not also induce me to rectify. New data have flowed in, and with the frankness of one of my predecessors, I also now read my recantation* (Greenough, 1834, p. 69).

After decades studying new evidence, Greenough saw the fossils he once attributed to a global flood had been deposited in multiple events, as were the mysteriously out-of-place boulders scattered across Europe.

The most famous reversal of opinions regarding the efficacy of a global flood was that of the Reverend William Buckland, Oxford's first professor of geology. In his 1819 inaugural address, Buckland argued that the geologic record supported a global flood. Several years later, he trumpeted the discovery of a mud and bone filled cave near Kirkdale as confirmation of a cataclysmic deluge. But after decades of field study throughout England and across Europe, Buckland eventually concluded that no geologic or geomorphic signature of Noah's flood existed (Buckland, 1836). In his famous Bridgewater Treatise volume, he retracted his published views and acknowledged evidence for a long series of geological catastrophes.

> *Discoveries which have been made, since the publication of this work, shew that many of the animals therein described, existed during more than one geological period preceding the catastrophe by which they were extirpated. Hence it seems more probable, that the event in question, was the last of the many geological revolutions that have been produced by violent irruptions of water, rather than the comparatively tranquil inundation described in the Inspired Narrative* (Buckland, 1836, v. I, p. 95).

By the 1830s it was becoming apparent that a global flood could not explain European rocks and topography. Buckland's student, Charles Lyell, lamented all the time wasted in trying to fit field evidence into the story of Noah's Flood. Attributing geological and geomorphological phenomena to a global flood had hindered progress in understanding the world.

> *Never did a theoretical fallacy, in any branch of science, interfere more seriously with accurate observation and the systematic classification of facts* (Lyell, 1830, v. 1, p. 29–30)

Lyell advocated for Hutton's view that the gradual work of processes that could still be observed in operation today explained geology and topography. Their view became the foundation of uniformitarianism.

Lyell thought that waves and currents shaped topography during a time of higher sea level. The theory of marine erosion became popular as the idea of a global flood faded from geological consciousness. The day-to-day action of waves worked powerfully to shape coasts. At mid-century many geologists thought that hills and valleys had been carved beneath the sea. Only in the 1860s did the leading advocates of the marine denudation theory convert to belief in the power of rivers to carve valleys.

Nineteenth-century arguments between catastrophists and uniformitarians centered on the interpretation of field evidence and whether the gradual operation of processes like those now in operation could have produced modern landscapes. Over the course of the century, the two camps gradually converged as the number of deluges that catastrophists needed to explain the field evidence increased. By mid-century general consensus among geologists held that Noah's Flood could not have deposited all the sedimentary rocks, carved global topography, or deposited surficial deposits of gravel, sand, and boulders.

No mainstream geologist still believed in a global flood. Neither, it turns out, did mainstream theologians. But what did deposit giant out-of-place boulders around northern Europe?

If you are confident you know the right answer before you look at something, you are all the more inclined to see supporting evidence. Expectations color perceptions. This was certainly true when extensive European gravel beds were interpreted as products of Noah's Flood. But new data or a change in perspective can turn confusing patterns into a clear story. And Swiss naturalist Louis Agassiz's recognition that glaciation radically altered the face of Europe pretty much finished off serious geological thinking about Noah's Flood (Agassiz, 1840). Agassiz's glacial theory was based on field observations that led to his then radical theory about an age of ice.

Charles Darwin later recalled an 1831 fossil-hunting expedition on which he completely overlooked the obvious-in-hindsight evidence for glaciation in the Welsh mountains (Macdougall, 2004). It was easy to miss something one was not looking for.

> *How easy it is to overlook phenomena, however conspicuous, before they have been observed by anyone … neither of us saw a trace of the wonderful glacial phenomena all around us; we did not notice the plainly scored rocks, the perched boulders, the lateral and terminal moraines* (Macdougall, 2004, p. 16).

No obvious analog existed for ice sheets before those of Greenland and Antarctica were known. Until then, the idea of ancient ice sheets seemed outlandish in places hundreds of miles from the nearest glacier. Without a theory to fit evidence into, geologists overlooked the significance of the landforms that later provided a convincing demonstration of extensive ancient glaciation.

In the year that Louis Agassiz unveiled his glacial theory, John Pye Smith (1774–1851), Principal of London's Homerton Divinity College, offered what he thought was the novel suggestion that Noah's Flood affected a limited area and wiped out humanity's ancestral homeland in *On the Relation between the Holy Scripture and Some Parts of Geological Science* (1840). In the tradition of Aquinas, Smith argued that geological revelations were fundamental truths, comparable to and compatible with biblical truths. Smith did not doubt the historical veracity of Noah's Flood. He pointed out that most nations had a flood tradition, although he cautioned that all that could be certain from this was that the flood affected the ancestors of all nations. A local flood could have wiped out humanity's ancestral homeland.

Reluctant to invoke uncalled for miracles, Smith rejected a violent cataclysm. Instead, he proposed that a gentle flood wiped out humanity somewhere in central Asia now below sea level, such as the Caspian Sea. Smith reminded his readers that geological evidence could be used to help sort through various interpretations of Genesis. Holding that any apparent discrepancy between geology and scripture *vanishes before careful and sincere examination*, he called for reinterpreting the Bible when biblical interpretations were shown to conflict with geologic evidence (Smith, 1840, p. 20).

Smith held up the stunning reversals of Buckland and Greenough as a compelling demonstration of the strength of geological evidence. He thought that field evidence capable of motivating such men to abandon deeply held convictions must have been genuinely convincing.

> *The annals of science, or of literature, or of theology, do not present a nobler instance of fairness and mental integrity, than was shewn by … geologists … in yielding up a favourite and long cherished opinion, to which they had committed themselves in the most public manner, and for which they had been hailed with flattering applause; knowing also, by a very sure anticipation, that the concession to the power of evidence, the avowal of honest conviction, would expose them to the*

censures of some, who 'understand neither what they say, nor whereof they affirm' though they speak and write with a confidence in the direct proportion of their incompetency to say or affirm upon good grounds (Smith, 1848, pp. 88–89).

Smith described how geologists initially thought diluvium was a single formation, a conclusion that supported the idea of a universal flood. But subsequent examination of distinctive minerals in the deposits revealed multiple sources. In some places the sediments came from nearby, in others they came from distant mountains. Deposits of various ages were found, with older drift buried below younger drift. The idea that one great flood deposited it all did not fit the field evidence.

Smith reluctantly described the ideas of those who still insisted on the reality of a globe-wrecking flood as *calculated to mislead the confiding reader* (Smith, 1848, p. 152).

The worthy persons who oppose what I may, not assumingly, call the whole body of geologists, … take up an alluring book, Professor Buckland's Bridgewater Treatise, perhaps, or Mr. Lyell's Principles; or, more probably, they may have been content with some of the older and very defective authors. From this they select a few statements, which, by their want of previous knowledge, they are exposed to no small risk of failing to understand. Of the great number of facts necessary to be known, many are overlooked, and many are forgotten; and among them are some which … vitiate the entire body of conceptions which the hasty compiler is forming. … In the end, he is surprised and grieved, and perhaps irritated, that the geologists do not adopt his views (Smith, 1848, p. 151).

In attacking the work of so-called scriptural geologists with marginal geological training, Smith noted how they generally proposed ideas with little to no regard for field evidence accumulated by generations of geologists and natural philosophers.

Granville Penn, an assistant clerk in the British War Department and grandson of William Penn (founder of Pennsylvania), argued that the world was created in six literal days about 6000 years ago in his *Comparative Estimate of the Mineral and Mosaical Geologies* (1822). Cuvier was simply mistaken about all those revolutions in Earth history; only two occurred. At the Creation God depressed some areas to hold the seas and then 1656 years later he switched things up, elevating the oceans and depressing the continents, triggering Noah's Flood and wiping out everything and everyone not aboard the ark. Penn claimed his insights were based on combining Genesis with Newtonian physics to arrive at the plain truth.

Despite this curious nod to scientific authority, Penn invoked the God-just-made-it-to-look-that-way argument to explain away problematic field evidence. God created rocks to look like they had been formed by natural laws not yet, but about to be, in force. Rocks were made *in correspondence with the laws which He was then about to establish, and in anticipation of effects and appearances which were thenceforward to be produced only by the operations of those laws* (Penn, 1822, p. 77). There was no point in trying to read the geologic story as actual events if rocks just looked like natural processes formed them. Penn was confident that field-evidence-based attempts to decipher Earth history were futile.

Although he promoted a strict literal interpretation of the Bible, Penn did not insist on a literal interpretation of all aspects of the biblical flood story. The ark had not actually carried pairs of every animal on earth. Mammoths went extinct as part of God's plan, even if it was not spelled out in the Bible. And because no vegetation could have survived a yearlong flood, God must have recreated land plants afterward. Penn also had an answer for why rivers, named in the biblical description of the Garden of Eden, were still recognizable geographical features. He considered this problematic passage a later parenthetical aside inserted into Genesis long after Moses wrote it and, thus, had no bearing on thinking about the Flood. So in defending his literal interpretation of the biblical flood story, Penn introduced nonliteral interpretations, added extra miracles not mentioned in the Bible, and even disowned some biblical passages.

Another influential self-taught scriptural geologist, George Fairholme, defended the geological and geomorphological effectiveness of Noah's Flood in his *New and Conclusive Physical Demonstrations Both of the Face and Period of the Mosaic Deluge* (Fairholme, 1837). Ignoring among other evidence the widely acknowledged problems presented by breaks in the rock record (such as Hutton's unconformity) and the thick sections of steeply dipping strata of constant thickness that stretched across Europe, Fairholme argued that sedimentary rocks were quite young and deposited rapidly. Besides, Fairholme argued that there simply could not have been geological revolutions before Noah's Flood. For if the driving force behind such convulsions was sin, how could they have occurred before the advent of sinners?

Fairholme claimed that geologists who argued for more than one grand catastrophe denied the authenticity and truth of the Bible. Why would God have sent great floods to repeatedly destroy the world before mankind existed when the very purpose of the Flood was to punish humanity for its wickedness? Recycling discredited ideas, scriptural geologists ignored or cavalierly dismissed the discoveries of Hutton, Cuvier, Buckland, and Lyell. In return, no working geologist gave them any credence.

7. Testimony of the rocks

Nineteenth century theologians increasingly concluded that when geological evidence conflicted with scriptural interpretation it was the latter that should adapt. Influential geologists on both side of the Atlantic likewise promoted the idea that scientific investigations that unearthed natural revelations helped to clarify scriptural interpretation. The mainstream scientific and theological consensus was that one should evaluate field evidence on its merits and adapt geologic theories and biblical interpretations accordingly.

In North America, Edward Hitchcock (1793–1864) helped shape attitudes toward the Flood. A prominent member of the National Academy of Sciences, President of Amherst College, Professor of Geology and a Calvinistic theologian, Hitchcock tried to *assure the world, especially any skeptics of science, that every finding of geology could … be corroborated in revelation, so that there was never any contradiction between the two accounts of nature* (Young, 1995, p. 141). Unusual for a geologist in his day, he wrote for theological and ecclesiastical journals arguing that geology could help evaluate conflicting interpretations of the biblical account of the creation and Noah's Flood.

Hitchcock made his case in a lengthy three-part article in *The American Biblical Repository* (Hitchcock, 1837–1838). In the first part, he reviewed flood traditions and argued that too many similarities existed for the stories to be unrelated. In the second, he reviewed the history of ideas about geological evidence for the Flood. Although he understood why seventeenth and eighteenth century natural philosophers accepted flood geology, it was a mystery to him as to how anyone could still maintain that topography and the fossil record was a product of a global flood based on outdated works like those of Burnet and Woodward. Outraged at the practice of calling geologists atheists simply because their studies endorsed allegorical rather than literal interpretations of the Bible, Hitchcock accused scriptural geologists of distorting scripture as well as geology.

Most of all, Hitchcock rejected the scriptural geologists' claim that secondary rocks formed in the interval between the Creation and the Flood and that the overlying tertiary and diluvial strata were deposited by the Flood. Such ideas had already been disproved. The deeper down in the strata one looked the greater the differences one found between the fossils and modern fauna. And the only way to attribute the preponderance of extinct creatures in the fossil record to Noah's

Flood was to invoke a second round of creation involving completely new species—something that would render the ark itself unnecessary.

In his third article, Hitchcock addressed the veracity of the Mosaic account of the Flood. After reviewing the major problems with accepting the biblical account, he argued for a local flood because science contradicted a simple reading of scripture, and biblical interpretations needed to be revised to harmonize the Bible with nature.

He later commented on the turbulent history of thinking about Noah's Flood in his *Religion of Geology* (1852).

> *The history of opinions respecting the deluge of Noah is one of the most curious and instructive in the annals of man. … This is a subject which men are apt to suppose themselves masters of, when they have only skimmed the surface. … Almost every geological change which the earth has undergone, from its centre to its circumference, has, at one time or another, been ascribed to this deluge. And so plain has this seemed to those who had only a partial view of the facts, that those who doubted it were often denounced as enemies of revelation. But most of these opinions and this dogmatism are now abandoned, because both Nature and Scripture are better understood* (Hitchcock, 1852, p. 112).

Hitchcock argued for a local flood because it was clear by then to geologists that Louis Agassiz's Ice Age explained most of the geologic evidence formerly ascribed to Noah's Flood. So Hitchcock endorsed Lyell's idea that flooding into the structurally low basin of the Caspian Sea drowned the ancestral homeland of humanity.

Back across the Atlantic, Hugh Miller (1802–1856) popularized such views. As a young stonemason, Miller was intrigued by fossil fish that occasionally showed up in the rocks he worked. Studying those exposed in quarries along the Scottish coast, he developed a reputation as a serious geologist after publishing *The Old Red Sandstone* in (Miller, 1841). A devout Presbyterian who edited the primary publication of the evangelical wing of the Church of Scotland, Miller's dual grasp of geology and theology convinced him that rocks posed no threat to Christianity. A prolific writer of popular books with a gift for clear expression, Miller became a leading voice among those seeking to harmonize geological and biblical interpretation.

Miller thought deluge traditions all referred to an ancient flood, but rejected the idea it was global. In his view, no need existed to fly in the face of geological evidence if there was no chance of really ever knowing exactly what happened. Trapped on the ark, Noah and company could not have known the extent of the flood. And everyone else died. Perhaps God could have spelled it all out more clearly, but the Bible was written for moral not scientific purposes. Miller warned against relying on the Bible to discern geographic, geologic, or astronomical facts. A plain-sense reading of the story carried the same dangers that befell those who thought the Bible placed Jerusalem at the center of the universe.

Miller argued that the Bible conveyed what it was intended to teach —the way to spiritual salvation—but that time and again when men *sought to deduce from it what it was not intended to teach, — the truths of physical science, — they have fallen into extravagant error* (Miller, 1866, p. 306). Asserting that scientific advances could shed light on biblical interpretation, he warned against the ignorance of those who sought to solve scientific problems with biblical interpretation.

Miller noted that for half a century no paleontologist or geologist had believed that rocks held evidence of a global flood. Those seeking evidence for the biblical flood had turned to the overlying surficial deposits—until that too proved fruitless. Adopting Lyell's solution to the puzzle of Noah's Flood, Miller argued for a central Asian flood that filled the basin of the Caspian or Aral Sea. Noting how the shore of the Caspian Sea was littered with salt and seashells that proved it was far more extensive at some time in the past, he concluded that anyone unfortunate enough to have been in the basin when it filled with water would have seen a great flood submerge their world.

Hitchcock and Miller were devout Christians, well versed in conventional theology. They viewed geological evidence that contradicted traditional conceptions of Noah's Flood not as a threat to their faith but as an opportunity to better understand Genesis. With their orthodox theological credentials, they were deeply committed to finding the truth in scripture and nature. Along with mainstream theologians, they adapted their reading of Genesis to accord with geological discoveries.

By the 1860s, virtually no geologist believed in a global flood. Scottish geologist Archibald Geikie described the situation as a debate that was over.

> *At the present day it seems altogether superfluous to raise the ghosts of the old floods and debacles, which, after playing so active a part in the early history of geology, have now for a good many years been quietly consigned to oblivion. Few now seriously hold the belief, that the phenomena of the Drift are due to a vast cataclysmal deluge...* (Geikie, 1863, p. 73).

Few Christian scholars still believed they lived on a planet not much older than the pyramids. Reverend Richard Main pointedly summarized the conservative Anglican perspective: *Some school-books still teach to the ignorant that the earth is 6000 years old. … No well-educated person of the present day shares that delusion* (Roberts, 2007, p. 39). Although old views on Noah's Flood continued to be pushed by those stubbornly arguing for the literal authority of Scripture, such voices were increasingly relegated to the fringe as the idea of a local flood became conventional among theologians as well as geologists.

When geomorphology gained recognition as a distinct discipline after the International Geological Congress of 1891, the view that Noah's Flood was a regional event was widely accepted by educated Christians around the world. The theory of a global flood sank beneath the weight of geological and geomorphological evidence for a long, complicated, and regionally varied history of landscape-forming processes and landscape evolution.

8. Field and theory today

Field observations shaped and reshaped geologic and geomorphic theory (as well as theology) as the search for evidence of Noah's Flood moved from deformation and collapse of the whole crust to the formation of fossiliferous sedimentary rocks before finally focusing on surficial deposits and topography. Eventually, the weight of field evidence compelled abandonment of the influential theory of a global flood. The relationship between field observations and theories is as pertinent today as it was during centuries of debate over Noah's Flood—expectations still color perceptions.

The productive tension between field and theory shaped influential twentieth century advances such as the development of plate tectonics, the recognition of megafloods, and efforts to quantitatively model landscape evolution. Today, uniformitarianism and catastrophism are no longer diametrically opposing incongruities. They offer complementary frameworks for understanding the story of particular landscapes. Whereas the experience of J Harlen Bretz provides a well-known example of the value of field evidence in evaluating theories, the basic point remains essential for any field geomorphologist or theoretician.

The historical lesson is as simple as it is obvious. Faith in theory should never trump data. And yet, field evidence makes sense only if interpreted through a reasonable theory. That this back-and-forth partnership between field and theory provides friction that helps drive advances in understanding both is as valid today as it was during the days before geomorphology emerged as a distinct discipline. The recent explosion in computational power and the resultant leap in the ability to simulate geomorphological processes and landscape evolution has brought some aspects of geomorphology back to the situation where well-developed theory threatens to overshadow scarce field data. Conversely, the growing abundance of detailed topographic data through the availability of LiDAR data opens the door for new theories. What is certain, however, is that the friction between field and theory provides the traction that advances geomorphological thinking, and is as essential today as ever before.

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