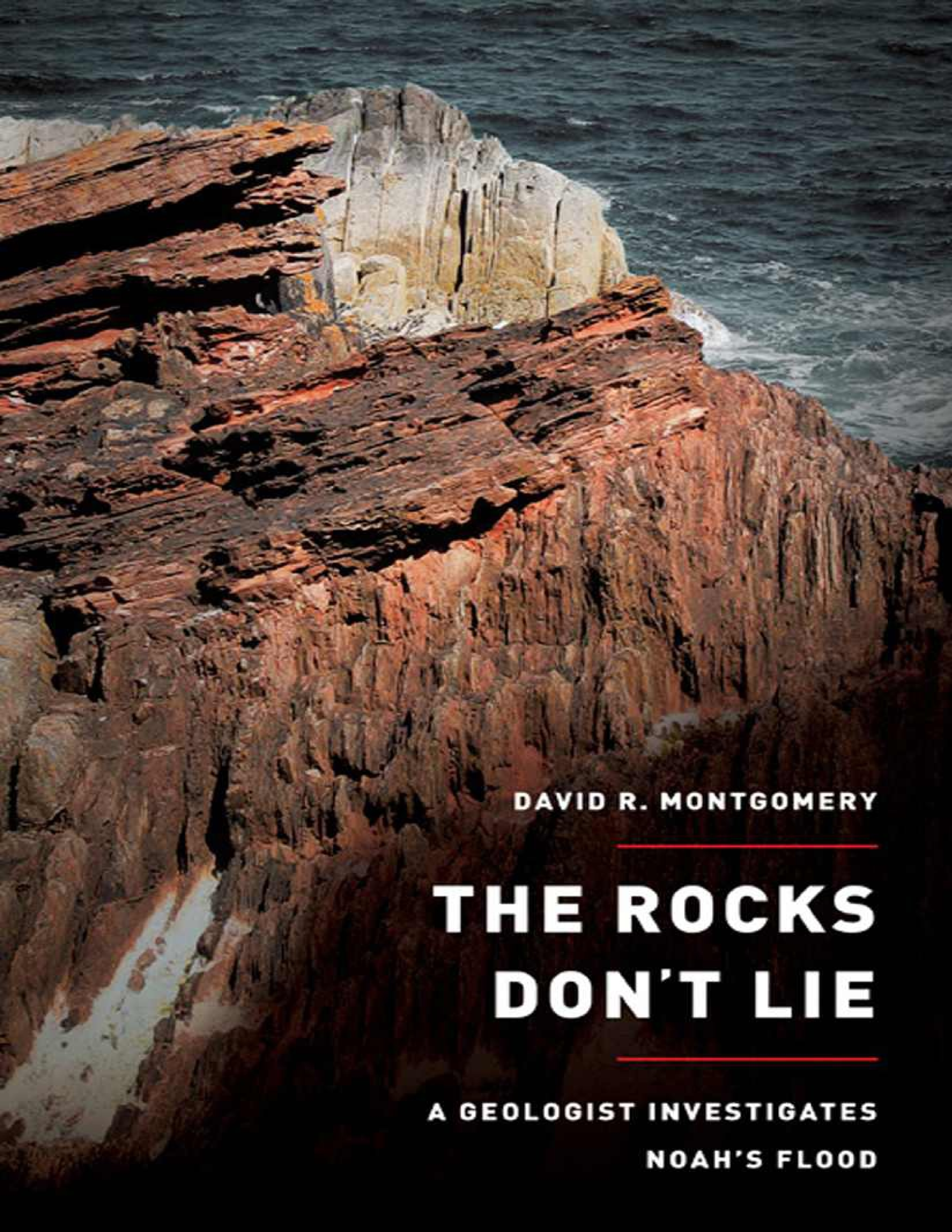


DAVID R. MONTGOMERY

THE ROCKS DON'T LIE

A GEOLOGIST INVESTIGATES NOAH'S FLOOD

7

Catastrophic Revelations

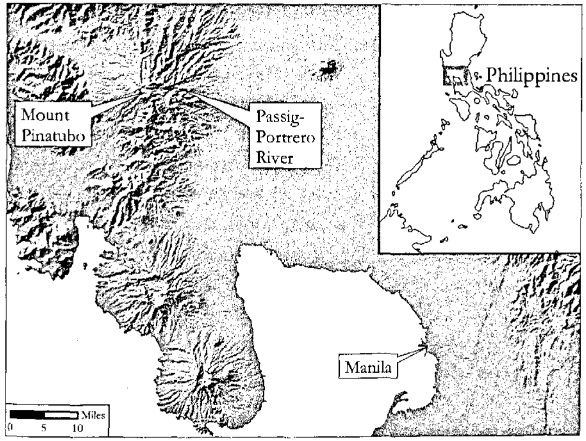
Before the early nineteenth century, natural philosophers paid little attention to deposits of loose gravel, sand, and boulders lying above solid rock. But northern Europe's geological blanket of unconsolidated material became far more interesting once it was thought that the part of earth history that overlapped with human history was preserved in surficial sediments rather than in the solid rock below. It helped that geology arose as a science in countries that had been glaciated, where a regional cover of glacial deposits—gravel, sand, boulders, and mud—resembled what you might expect a big flood to leave behind. These surface deposits and topography, the form of the land itself, became the link between the modern world people knew and the former worlds preserved in the rocky depths of geological time.

I came to appreciate the potential for catastrophic rearrangement of surficial deposits in the Philippines. At the time, I was doing fieldwork in the Pasig-Potrero River, where one of my graduate students was studying changes after the catastrophic 1991 eruption blew the top off Mount Pinatubo and buried the surrounding countryside under hot pumice and ash. The whole landscape around the volcano changed, as river valleys filled in with sediment only to have great canyons cut back down hundreds of feet into the loose debris in just a couple of years. We saw the Passig-Potrero River as an ideal place to study how rivers behaved when supplied with as much sediment as they could carry.

On a beautiful tropical morning, we started out from Delta 5, an abandoned military checkpoint perched on a rock outcrop sticking up from the riverbank. We headed upstream, leaving the coastal plains to enter the volcanic upland. Walking up the riverbed, we surveyed it in three-hundred-foot sections. One person would stay behind, sighting through a tripod-mounted level, as another took our stadia rod—a giant collapsible ruler—out to the end of a long tape measure. Using the level to read off the elevation every few feet as we moved the stadia rod along the tape, we measured the elevation of the riverbed. Repeating the survey over a number of years gave us a record of how the river ate down into the volcanic debris as lahars—volcanic mudflows—surged downstream to bury villages and towns beneath a blanket of sediment.

Just before lunch we noticed that an ominous black cloud had settled in over the volcano several miles upstream. The river started rising as we kept surveying our way up through a tight canyon. When the flow got deep enough to start moving the riverbed, grapefruit-sized rocks rolled into our shins and we decided to break for lunch on a sand terrace five or six feet above the water level. About halfway through lunch we noticed the water rising even faster. As the river started lapping up onto our lunch-stop terrace, we retreated to the foot of the canyon walls and watched six-foot-high waves cascade down the river we had walked up all morning.

Alarmed, we climbed up through narrow side channels that had cut down through the volcanic debris—the only other way out of the



Map of the Philippines showing location of Mount Pinatubo and the Pasig-Potrero River draining off the volcano's eastern flank.

canyon. By the time we reached the top of the side canyon we could see our lunch spot, several hundred feet below, submerged beneath a roaring torrent of bouncing boulders. We perched for the afternoon, trapped on the ridgetop but enthralled by walls of water crashing down the canyon. Here in front of us was a graphic illustration of what had drawn me to geology in the first place: Earth's appearance of being stable—of being solid as a rock—only held some of the time.

In the early nineteenth century, the conventional view was that grand catastrophes reshaped landscapes in a geologic jiffy. The idea that the slow pace of everyday change could shape and reshape the world was considered delusional fantasy. By the end of the century, geologists believed that everyday erosion was how the world worked, and grand catastrophes had become geologically taboo.

Scientific curiosity and religious conviction were not alone in pushing efforts to better understand regional geology. Just as demand for iron and coal drove advances in mining and mineralogy, construction of railroads and canals created a need to understand regional geology. As necessity and practical interest grew, schools in industrializing areas began to appoint professors of geology. Studying rocks could be more than just an inspired hobby for those with the time, means, and inclination to seek insight into nature's inner workings. It could be a livelihood. As geologists began to work out the details of local and regional geology, they reassessed the role of Noah's Flood in earth history.

In 1815, surveyor and canal builder William Smith worked out the structure of England's layered rocks in compiling what is widely credited as the first regional geologic map. He carefully documented a consistent, well-ordered succession of rock types across England that was far too systematic to have formed during the chaos of a globe-wrecking deluge. Smith also showed that different layers of rock consistently held different fossils. Based on observations collected over years of field excursions, Smith's carefully compiled map allowed him to accurately predict the type of rock and the fossils in it virtually anywhere in England. His obsession with perfecting his map bankrupted both himself and the idea that a single catastrophic flood deposited layered rocks. After he published his map, geologists no longer looked for Noah's Flood in the rocks. Instead they looked for signs of a great flood in topography and surficial deposits.

Across the English Channel, Smith's contemporary Georges Cuvier, the vertebrate paleontologist who had dismissed Scheuchzer's flood victim and concluded that mammoths were extinct, was busy mapping the rocks in the countryside around Paris. He found a sequence of distinctively terrestrial rocks containing fossil quadrupeds that alternated with layers full of fossil seashells. He knew that a single flood could not produce a thick sequence of interlayered

terrestrial and marine rocks. Clearly, the sea inundated the land not just once but time and time again. Further fieldwork in the Paris basin unearthed evidence for alternating periods of fresh and saltwater inundation that Cuvier interpreted as evidence for at least half a dozen great floods, each of which ended a geological era. Instead of Hutton's grand engine of slow change, Cuvier's 1813 *Essay on the Theory of the Earth* concluded that each catastrophe recorded another transition in a long series of geological eras. Ever since, these two views of geologic change—slow and steady versus catastrophic—have framed competing theories for how the world is shaped.

The idea that a catastrophic biblical flood could have remodeled the European landscape was vividly reinforced in 1818, when the Getroz glacier dammed the river Dranse in Switzerland's Val de Bagnes. Advancing like the glacier that dammed the Tsangpo in Tibet, the ice blocked the river and a lake holding eight hundred million cubic feet of water formed above the frozen impoundment. When a tunnel was cut through it to draw down the lake, the ice and debris dam failed, sending a wall of debris-charged water surging down the valley at more than thirty feet a second. The flood swept away landmarks as sand and mud filled the local church to the pulpit. Huge boulders lay strewn around the fresh deposits. As residents dug out from the mess, they discovered trees and houses swept away in the torrent. The event impressed natural philosophers with how catastrophes could blanket large areas under sediment. Here, perhaps, was an analog for the geological signature of really big floods. The deposit left by this modern catastrophe looked a lot like the blanket of sand, gravel, and mud that covered much of northern Europe.

Again, Cuvier led the way in elaborating the power and dynamism of geological processes in his 1825 *Discourse on the Revolutions of the Globe*. He made the case that distinctive animals lived during different epochs of earth history and described how abrupt discontinuities between geological formations with different fossil assemblages testified to periodic catastrophes having remodeled the world. In his view, the most recent catastrophe was a sudden flood that separated the relatively short history of humanity from the depths of geologic time. Cuvier's contention that one could not explain the geologic record solely by means of existing causes—that the processes that shaped Earth's surface were different in the past—became known as catastrophism, and stood in direct contrast to Hutton's articulation of how things happened gradually through many small changes, a view that became known as uniformitarianism.

Cuvier's idea of periodic cataclysms seemed to address otherwise perplexing observations. His compelling evidence for the repeated destruction of former worlds inspired geologically literate clergy to reinterpret Genesis. As early as 1816 the Stackhouse Bible cautioned readers, "Moses records the history of the earth only in its present state. . . . There is nothing in the sacred writing forbidding us to suppose that [fossils] are the ruins of a former earth."[1] Fossils now belonged to numerous ancient catastrophes. Geological evidence was starting to shape biblical interpretation.

A prominent Protestant, Cuvier did little to counter the impression that the most recent of his long series of grand catastrophes was the biblical flood. He asserted it could not have been all that ancient: "If there is any circumstance thoroughly established in geology, it is that the crust of our globe has been subjected to a great and sudden revolution, the epoch of which cannot be dated much farther back than five or six thousand years ago."[2] He thought that a small number of people and animals survived the most recent cataclysm, about the time conventionally ascribed to Noah's Flood.

Those seeking geological support for the biblical flood now looked to the sediments on top of the rocks, assuming Noah's Flood was a more recent catastrophe than the geological revolutions recorded in hard rock. The most influential nineteenth-century diluvialist was William Buckland, a minister in the Church of England and

Oxford's first professor of geology. He passionately defended the traditional view of Noah's Flood but acknowledged that the six days of Creation could not be taken literally. The son of a clergyman, Buckland knew that geology would instantly become a respectable science if he could show that it validated the Genesis flood.

A man of his times, Buckland straddled both worlds—those of the church and field geology. He wanted to forge links between human history as recorded in classical texts and biblical stories and earth history as revealed by geology. Like many of his contemporaries, he believed that Moses disregarded most of earth history because it did not concern mankind.

Confident of the reality of Noah's Flood, Buckland saw its signature in the sculpting of topography and the geologically recent deposition of the blanket of gravel covering much of Britain. He saw geological evidence as supporting the universality of the Deluge. What else could explain the giant out-of-place boulders in northern Europe from Norway to the Alps? Made of rock with no local source, boulders the size of barns had obviously been transported from distant sources. A really big flood seemed like the only reasonable way to explain how to move huge rocks. Lacking reasonable alternatives, Buckland and his contemporaries attributed the deposition of the gravel blanket and transport of enormous boulders to great waves during the biblical flood.

In his 1819 inaugural address at Oxford, Buckland equated Cuvier's most recent catastrophic inundation with Noah's Flood.

> *The grand fact of an universal deluge at no very remote period is proved on grounds so decisive and incontrovertible, that, had we never heard of such an event from Scripture, or any other, authority, Geology of itself must have called in the assistance of some such catastrophe, to explain the phenomena of diluvian action which are universally presented to us, and which are unintelligible without*

recourse to a deluge exerting its ravages at a period not more ancient than that announced in the Book of Genesis.[3]

Although the remains of modern species buried in the surficial gravels pointed to a recent calamity, Buckland did not believe that Noah's Flood formed fossil-bearing rocks. To find evidence of the Flood you had to look in the overlying unconsolidated sediments and at the lay of the land, the form of topography.

In Buckland's opinion, Europe's surficial gravel was too extensive to have been laid down by rivers. He thought the Flood simultaneously deposited it and carved the modern landscape from older rocks. Buckland coined the term diluvium to describe the surficial deposits that mantled much of northern Europe and to distinguish them from alluvium, the sand and gravel laid down by modern rivers. He remained disturbed, however, that no human fossils had been found in diluvium. Where were the bones of those the Flood was sent to destroy?

Despite this troubling detail, Buckland stressed that geological facts were broadly consistent with the biblical account because Noah's Flood ushered in only the most recent of a long succession of worlds. Buckland's lecture, published as *Vindiciae Geologicae; or, the Connexion of Geology with Religion Explained*, argued that geological facts "are consistent with the accounts of the creation and deluge recorded in the mosaic writings. . . . The evidences afforded by Geological phenomena may enable us to lay more securely the very foundations of Natural Theology."[4]

The "Natural Theology" to which Buckland referred followed William Paley's popular and influential 1802 book of the same name. Paley argued that scientific revelations contradicting biblical interpretations provided natural guidance for better interpreting scripture because the Bible and the book of nature shared the same author. In the opening decades of the nineteenth century, even Pope Pius VII

endorsed viewing the six days of Creation as of indeterminate length rather than as a literal week of twenty-four-hour days. A little more than a decade after publication of Paley's popular book, in 1813, English geologist Robert Bakewell sought to reconcile the geological and biblical chronologies in his *Introduction to Geology*, the first geological textbook published in English, arguing that the Mosaic chronology began when the world became fit for human habitation.

Others argued that a long time passed between the initial Creation in the first verse of Genesis and the formless Earth of the second verse. Perhaps the time between when God created the world long ago and when he remodeled it for human use wasn't recorded in the Bible, leaving an indeterminate gap between the first two verses of Genesis. The gap theory, as this idea became known, provided an alternative to the day-age theory that each day of creation lasted far longer than twenty-four hours.

Two centuries ago, Christian scholars adapted how they read the Bible to account for geological revelations. And why not? The history of the world that geologists had found in the rocks followed the order of events described in Genesis—an initial period of time without life, followed by the introduction of plants and animals, and eventually people. If the days of Creation referred not to a single week of breakneck change but to a long series of geological ages, the problem that more than six days was needed to account for prehistory became an interpretive detail that did not imperil scriptural authority. Nowhere, Buckland asserted, did Genesis contradict the idea that the modern world was built upon the ruins of prehuman worlds. With one foot in the newborn profession of geology and the other in Anglican orthodoxy, Buckland was a man of deep conviction and few doubts.

Most geologists love the field aspect of our work, and Buckland appears no different. He went on field excursions across Britain and Europe, accompanying natural philosophers he visited and in the company of those visiting him. He traced the occurrence of durably hard yet smoothly rounded quartzite pebbles in surficial gravels from Oxford north to Warwickshire. There, he found these distinctive pebbles eroding from outcrops of conglomerate, rock formed when gravel and sand were buried deep enough to turn back into solid rock. This unusual formation was known as pudding stone due to the resemblance of the gravel set in a sand matrix to plums in a Christmas pudding. Through his geological sleuthing, Buckland reasoned that the quartzite pebbles had to have been rounded before being incorporated into the conglomerate. He thought that a great flood then ripped the distinctive pebbles back out of the rock, strewing them down the Thames all the way to London.

Buckland claimed that a great flood provided a better explanation for the distribution of the diluvial gravels than did other ideas—modern rivers were too small to account for regionally extensive gravel sheets or to move the largest boulders found in the deposits. And what at the time seemed like an apparently global distribution of similar deposits was thought to demonstrate that a geologically recent flood had affected the surface of the entire world. Again, Buckland was confident that a great flood provided the best explanation for his geological observations.

It should come as no surprise, then, that he marveled over what he considered proof of Noah's Flood when workmen in 1821 discovered a bone-filled cave near Kirkdale in Yorkshire. One of the first to explore the cavern, Buckland stumbled upon a bewildering variety of bones, including those of hyenas, tigers, elephants, rhinoceroses, and hippopotamuses. All these bones were embedded beneath stalactites in the red mud of the cave floor. It was a spectacular discovery indeed.

How did the bones of so many African species get mixed up together in a British cave? Seeing how some of the bones were gnawed, Buckland concluded hyenas had dragged them into their den long before the Flood, which he thought washed in the cave's uppermost layer of red mud and more bones. The thin stalactites capping the mud confirmed a recent origin, consistent with Cuvier's most recent geological catastrophe of five or six thousand years ago.

Inspired, Buckland gathered geological facts thought to demonstrate the reality of Noah's Flood into his 1823 *Relics of the Flood*. In it he described great accumulations of bones in "superficial and almost universal deposits of loam and gravel, which seems impossible to account for unless we ascribe them to a transient deluge, affecting universally, simultaneously, and at no very distant period, the entire surface of our planet."[5] The case for Noah's Flood appeared to build once again, this time in the interpretation of surficial sediments.

Buckland combined his description of Kirkdale Cave with a synopsis of similar evidence for a recent deluge from other European caves. The continent's surficial gravel contained exotic fossils like those from Kirkdale Cave and unlike modern species. Other evidence included giant blocks of granite from Mont Blanc scattered well beyond the Alps. Rejecting a southern origin for the Flood, he argued that Europe's surficial gravel and stray boulders came from identifiable northerly sources. He also maintained that the violent floodwaters carved valleys far too deep and wide to have been cut by the piddling rivers that flowed through them today.

In coming to these conclusions, Buckland relied on what he saw with his own eyes. Nowhere did he invoke scriptural authority, even if it framed his view. His reasoning was compelling enough that others hailed his explanation as vindication for the reality of Noah's Flood. Like Cuvier, he did nothing to discourage the idea. After all, his defense of a global flood had its rewards. Even before his work on Kirkdale Cave, Buckland received the Royal Society's prestigious Copley Medal. Appointed Canon of Oxford's Christchurch Cathedral three years later, he eventually became Dean of Westminster, one of the most prestigious positions in the Anglican Church.

Buckland was hardly alone in thinking he had found evidence of Noah's Flood. Adam Sedgwick, who held Woodward's old chair as professor of geology at Cambridge and taught Darwin his geology, summarized conventional thinking in 1825.

> *The sacred records tell us—that a few thousand years ago 'the foundations of the great deep' were broken up—and that the earth's surface was submerged by the water of a general deluge . . . [which] has left traces of its operation in the diluvial detritus which is spread out over all the strata of the world.*[6]

Not long afterward, cracks began developing in Buckland's geological case for a global flood.

The end began when flood skeptics like John Fleming, an evangelical pastor in the Church of Scotland and professor of natural philosophy at Aberdeen, questioned the arguments and conclusions of flood champions like Cuvier and Buckland on theological as well as geological grounds. Fleming's 1826 article in the *Edinburgh Philosophical Journal* used logic and literal interpretations of scripture to challenge Buckland's version of the Flood.

Fleming opened with the problem of how Buckland could attribute extinctions to the Flood when the Bible said that two of every creature boarded the ark. If Noah saved a pair of all the world's animals, then geologists could not blame extinctions on the Flood. And the biblical flood sounded like a relatively tranquil affair, leaving submerged olive trees intact after taking forty days and nights for the waters to rise. To Fleming, a literal interpretation of the biblical story was inconsistent with Buckland's view of violent currents capable of carving deep valleys into hard rock and transporting huge boulders and carcasses halfway around the world. Fleming granted that a great flood could have swept away loose soil but doubted that so brief an event could have gouged out deep valleys. To the contrary, a literal reading of Genesis implied that the ark grounded out close to where Noah and his crew first embarked. Surely a flood powerful enough to reshape the world would strand Noah somewhere far from where he started.

Although Fleming made it clear that he did not question the occurrence of the biblical flood, he viewed the affair as tranquil enough to leave no geological signature. He considered it futile to look for physical evidence of the Flood.

Fleming also questioned Buckland's geological interpretations. A global flood would leave the same kind of mud in caves all across Europe. Yet the mud one found varied with the local geology. And if the mud wasn't washed in from afar, how could the fossils entombed in it have been?

Fleming's critique continued with summarily dismissing the theory that the elephantlike bones and carcasses found in Siberia and North America came from tropical regions. The intact skeletons ruled out long-distance transport by a violent deluge. Pointing to Cuvier's anatomical studies, Fleming argued that the thick hair covering mammoth carcasses showed they were native to cold regions. These behemoths were well suited to living where their bodies were found. Mammoths did not confirm the transporting power of the Flood.

Fleming even questioned Buckland's interpretation of Kirkdale Cave. While he agreed that the cave was an ancient hyena den, he thought that Buckland jumped to conclusions in attributing to a single flood the mud in which the bones were found. A succession of small floods could have deposited the mud.

Reverend Fleming chided geologists for rushing to find evidence of the biblical flood. In his view, misguided efforts to use geology to vindicate biblical interpretations would harm both science and Christianity.

More than Fleming's scathing critique, new geological discoveries eroded Buckland's faith in a universal deluge. Most problematic for a global flood was that explorers could find no diluvium in the tropics. Closer to home, it proved impossible to explain the complex stratigraphy of European diluvium through a single event, no matter how catastrophic. Buckland began to reconsider whether his imagination had run wild in his zeal to defend the biblical flood. A decade after Fleming first challenged him, Buckland capitulated when he was asked to prepare a volume commissioned by the estate of the Earl of Bridgewater to illustrate how geology revealed the wonder and wisdom of Creation.

In 1836, Buckland did something few others before him had done in attempts to reconcile geology and the Bible. He pulled a complete about-face when his Bridgewater volume *Geology and Mineralogy* repudiated his earlier view of diluvium. Instead, he endorsed the position that a tranquil Flood did little to Earth's surface, long after earlier catastrophes laid down fossil-bearing rocks and surficial deposits. Citing recent discoveries, Buckland advocated caution in trying to use the geological record to support literal interpretations of Genesis.

> *The disappointment of those who look for a detailed account of geological phenomena in the Bible, rests on a gratuitous expectation of finding therein historical information, respecting all the operations of the Creator in times and places with which the human race has no concern; . . . the history of geological phenomena . . . may be fit matter for an encyclopedia of science, but are foreign to . . . a volume intended only to be a guide of religious belief and moral conduct.*[7]

Although Buckland still maintained that a geologically recent inundation overwhelmed the northern hemisphere, his earlier confidence that it was the biblical flood lay shattered. He could no longer attribute fossils to Noah's Flood. Fossils were found in strata that accumulated

slowly over long periods of time. Even the surficial deposits recorded more than one event. Buckland had abandoned Noah's Flood.

Despite his change of mind, Buckland had no concern that geology and revelation would prove inconsistent.

> *Geology has shared the fate of other infant sciences in being for a while considered hostile to revealed religion; but, when fully understood, it will be found a potent and consistent auxiliary to it, exalting our conviction of the Power, and Wisdom, and Goodness of the Creator.*[8]

Secure as ever in his faith in both nature and the Bible, Buckland maintained that the question is not "the correctness of the Mosaic narrative, but of our interpretation of it."[9] In a philosophical turnabout, Buckland shifted from using geology to shore up a literal interpretation of the Bible to arguing that biblical interpretations could be tested through consistency with geological observations.

Coming from a conservative man of the cloth, Buckland's Bridgewater treatise drew immediate attacks from fellow clergy appalled by his recantation of geological support for the biblical flood. Outraged traditionalists who insisted on interpreting the Bible literally railed against this compelling dismissal of scriptural geology by a ranking clergyman steeped in Anglican orthodoxy.

What led to Buckland's stunning reversal? To a great degree it was his former spellbound student, Charles Lyell.

Born into a life of privilege the year James Hutton died, Lyell grew up exploring the New Forest in Hampshire, where his father pursued botanical studies and encouraged his son's interest in the family's extensive natural history library. Raised an Anglican, Lyell read Bakewell's just-published geology textbook in 1816, the year he enrolled at Oxford to study classical literature and law. Lyell was particularly struck by Bakewell's concept of a world much older than generally supposed based on a literal reading of Genesis. Equally intriguing to him, this unconventional idea came from the pen of someone who believed geology revealed the Creator's grand design.

Lyell attended Buckland's Oxford lectures each spring from 1817 to 1819. He came to accept that the biblical chronology referred to the time since the creation of people. Who could know how much time had passed before then?

Buckland's enthusiastic endorsement ensured Lyell membership in the Geological Society of London once he graduated. Society members overwhelmingly rejected Hutton's view of great cycles of gradual change driven by processes like those operating at present. Most advocated Cuvier's view of earth history as a series of violent catastrophes. On a visit to Paris the previous year, Lyell examined Cuvier's collection of fossils, describing them as "glorious relics of a former world."[10]

After graduation, Lyell divided his time between reading for the bar and traveling through Europe. Visiting Paris again in 1823 as a representative of the Geological Society, he met Constant Prévost, a colleague of Cuvier, who believed that the alternating freshwater and marine strata of the Paris basin were deposited gradually in a coastal inlet that periodically turned into a freshwater lake. Perhaps geological change could occur through observable causes, if given enough time.

The following year, in the fall of 1824, Lyell visited sixty-three-year-old James Hall at his estate on the Scottish coast. Now about the age Hutton was when they first sailed to Siccar Point, Hall took Lyell there to absorb Hutton's insight through his own eyes. Seeing firsthand how earth history involved a lot more time than conventionally thought, Lyell began to believe that gradual changes could shape the land.

That same year, Lyell joined Buckland for a geological excursion through Scotland. Although it may have been clear to both that their

views had started diverging, neither could have known that within a decade the apprentice would dethrone the master.

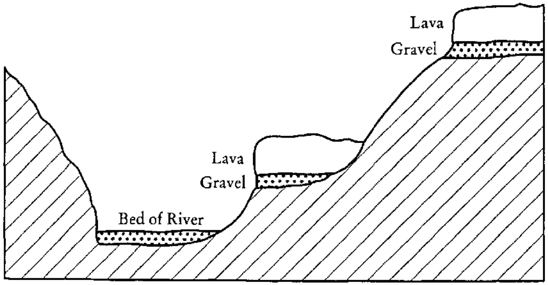
Lyell was not particularly interested in questioning religious views. Like many of his peers, however, he was deeply concerned about the effect that ignoring geological evidence could have on both science and religion. In 1827, he concluded a review of George Poulett Scrope's *Memoir on the Geology of Central France* with an appeal for interpreting Genesis broadly and letting the rocks speak for themselves:

> *We must recollect that the Mosaic narration is elliptical in the extreme, and that it makes no pretensions whatever to supply those minute scientific details which some would endeavour to extort from it.*[11]

Lyell was echoing Augustine in believing that it would be hard to convince rational men to follow a religion that denied things one could see for oneself.

Scrope's book was the culmination of extensive fieldwork in the Auvergne region, where dozens of conical hills made of loose piles of volcanic cinders overlook acres of black basalt. Deep valleys were carved into stacked lava flows on which these delicate cinder cones stood. Identical sequences of lava flows exposed in the walls on opposing sides of individual valleys proved that the river cut down into the lava. Lyell was intrigued by Scrope's description of how the lava flows buried the river gravels now exposed in the valley walls. Scrope's careful observations left no doubt that the lava had repeatedly filled a valley that the river just as often reexcavated. The layers exposed in the cliffs were not deformed and there was no evidence of catastrophic disruption. The valley-filling lava flows could be traced back to loose cinder cones sure to have been swept away by a flood capable of carving into hard rock.

The following May, Lyell set off to explore the region firsthand,



Lava flows emplaced over buried river gravels in Auvergne, France (based on Charles Lyell's 1833 Principles of Geology, *volume III, figure no. 61, p. 267).*

accompanying the influential Scottish geologist Roderick Murchison on an excursion through France. They visited Scrope's outcrops and studied the relationships between cinder cones, basalt flows, and river terraces. It quickly became clear to Lyell that a single flood could not have carved modern topography. Rivers slowly carved their own valleys.

From Auvergne, they traveled down the Rhone Valley to compare its rocks with those of the Paris Basin. Proceeding south into northern Italy, they traveled from Bologna to Florence and on to the Zoological Museum in Turin. Lyell realized that the rocks in the different parts of the regions they had just crossed had different fossils. Here was a formative realization for one who had never set out to become a geologist.

Fossils could be used to reliably assess the age of strata in southern Europe, something that could not be determined from mineral composition alone. The fossils in the younger rocks at the top of the regional geological pile were more like the modern fauna than were the fossils in the older rocks deeper in the section. The comings and goings of species from the fossil record could be used to track

geologic time. Lyell was hooked. Here was the key to the grandest puzzle. The fossils in different rock formations could be read to tell geologic time. If you knew the mix of fossils in a rock formation, you could confidently deduce its age relative to other formations.

When Murchison returned to London in August, Lyell traveled on to Sicily, ending his career as a barrister. He was now a geologist, by accident rather than design. More than anything else his exploration of European geology convinced him of the enormous span of geologic time and that a global flood was not responsible for shaping the modern landscape. Perhaps Hutton was right after all. Maybe slow, steady change was the pace at which the world worked.

On his way back to England, in February 1829, Lyell stopped in Paris to compare the fossils he had picked up with those in the collections of French geologists. The proportion of still-living species increased farther to the south—and higher in the regional stack of rocks. Older rocks, lower down in the regional pile, held more species not represented in the modern fauna. This didn't square with the traditional biblically inspired view that, except for the Flood, everything's been the same since the Creation.

The trip through France and Italy convinced Lyell to try to sway public opinion away from the misconception that Genesis precluded the immensity of geologic time. It was an ambitious goal. Geological findings that contradicted conventional biblical interpretations weren't common knowledge, and geological audiences favored Cuvier's grand catastrophes to explain the geologic record. Few favored Hutton's style of uniformitarian thinking in which everyday processes slowly shaped the world. Writing for two audiences, Lyell tried to counter the dominance of catastrophist thinking among his colleagues without shocking the general public accustomed to the idea that Noah's Flood resurfaced our six-thousand-year-old planet. In 1830, he put his legal training to work in his *Principles of Geology*, building up an argument and defense against the reactionary outcry sure to follow.

In presenting his case, Lyell began with a history of geology that turned the uniformitarian-catastrophist debate into a simplistic choice. Things either happened catastrophically or they happened gradually. Casting the debate between uniformitarianism and catastrophism as between rationality and superstition, he decried the tendency of previous generations to conjure up grand catastrophes when the steady action of processes still operating today could explain the world.

Eager to make his mark challenging catastrophists, Lyell also was keenly aware of his own need to secure a steady income. Geologizing did not pay the bills. So with an eye on securing a chair in mineralogy or geology, and not wanting to be too provocative, he kept references to the Mosaic chronology and the biblical flood to a minimum.

Lyell staked out a position opposing the habit of invoking grand catastrophes to explain geological evidence.

> *We hear of sudden and violent revolution of the globe, of the instantaneous elevation of mountain chains, of paroxysms of volcanic energy. . . . We are also told of general catastrophes and a succession of deluges, of the alternation of periods of repose and disorder, of the refrigeration of the globe, of the sudden annihilation of whole races of animals and plants, and other hypotheses, in which we see the ancient spirit of speculation revived, and a desire manifested to cut, rather than patiently to untie, the Gordian knot.*[12]

In cataloging observations on physical processes now in operation, Lyell emphasized how erosion and uplift occur episodically. He calculated that it could take a big river like the Ganges more than seventeen centuries to carry away the tremendous mass of rock uplifted by a single great earthquake.

Lyell argued that the laws of nature governing geological processes remain constant, even though their effects vary through time.

Contemporary reviewers misinterpreted this as advocating no role for catastrophes in earth history. But this was not what Lyell meant. He described the tremendous erosive power of floods resulting from the failure of topographic barriers holding back lakes, specifically linking catastrophic floods with earthquakes and volcanic eruptions. With this nod to geological catastrophes, Lyell argued that processes still in operation could carry on for long enough to sculpt topography.

In dispensing with the need for divine intervention after the initial Creation, Lyell had taken one more step on the path toward full abandonment of a global flood as a geological reality. By the third volume of his *Principles* he explicitly dismissed the likelihood that a global flood ever happened. Any current capable of gouging deep valleys into hard rock would have swept away the fragile cinder cones of central France. Besides, Lyell's reading of Genesis implied a tranquil flood rather than Buckland's raging waters. That an olive tree remained standing demonstrated little, if any, scriptural support for erosion during the Deluge. He saw no case for a globe-wrecking flood.

Lyell suggested that a local flood could have wiped out the then inhabited world if there had been "extensive lakes elevated above the level of the ocean" in a region with "large tracts of dry land depressed below that level."[13] He went on to describe how this might occur in various places. An earthquake that breached the topographic barrier holding back Lake Superior would unleash a mighty flood down the Mississippi River valley. The low ground surrounding the Caspian Sea sat three hundred feet below the Black Sea. Breach the barrier between these inland seas and the lower basin would rapidly fill with rising water. Lyell speculated that if even deeper depressions had existed in the past, similar situations could have flooded what previously had been mountains. Here were plausible processes by which great floods might occur.

Despite his care to avoid confrontational language, the implications of Lyell's views were not lost on the panel reviewing him for appointment to a position at King's College in 1831, a post he desperately needed. The decision was in the hands of an archbishop, a pair of bishops, and two medical doctors, each of whom had the right to veto Lyell's nomination. When Lyell was informed of their concern about his unorthodox convictions, he fired off a letter to explain that although it was clear that the Flood could not have covered the entire planet, there was no evidence that "the whole inhabited earth . . . may not have been deluged within the last 3 or 4,000 years."[14]

Lyell's artful dance worked. He got the job and made a point of quoting one of the bishops to conclude his second lecture: "it is impossible that true religion can be injured by the ascertainment and establishment of any fact . . . [no science] affords a greater number of illustrations of the power & wisdom exhibited in the creation than Geology."[15] To Lyell, his geology demonstrated the manifest wisdom of the Creator, which meant the challenge lay in correctly interpreting both the rocks and the Bible.

Lyell's careful arguments and exposition mollified some, although by no means all, critics. Soon after Lyell's book was published, Sedgwick attacked Lyell's insistence on the uniform operation of processes through geologic time. Catastrophes were necessary to explain the deformation of strata and how ancient seabeds could be lifted up to form new land. Lyell's carefully constructed arguments may not have worked on Sedgwick, but they began to convert Buckland.

Within a decade, new discoveries convinced Buckland that Lyell was right. The volcanic cones of central France really were compelling evidence that valleys had not been incised by a global flood. Buckland's own fieldwork demonstrated that the drift, the great gravel sheet he had long attributed to Noah's Flood, was not deposited in a single event. There had been several episodes of deposition involving material from different sources. In his Bridgewater treatise

Buckland reveals the influence of Lyell's *Principles* when he states that the physical laws governing geological processes were as uniform as the law of gravity governing the orbits of planets.

It was Buckland who bore the brunt of clerical attacks after his abandonment of Noah's Flood. Conservative clergy may have seen Lyell as a godless radical, but they saw Buckland—the former champion of biblical geology—as a traitor. A new breed of scriptural geologists and clergy with limited knowledge of geological discoveries rose to defend Moses and attack Buckland. They recycled the discredited arguments of Burnet and Woodward and invoked Noah's Flood to explain secondary rocks, fossils, and the lay of the land.

In one of the least vitriolic clerical responses to Buckland's recantation, William Cockburn, Dean of York, claimed that there was no more to earth history than an initial six days of Creation and Noah's Flood about a thousand years later. A clergyman known for railing against what he saw as anti-Christian scientific ideas and theories, Cockburn revived even then discredited reasoning creationists still use to defend their preferred interpretation of Genesis. He ignored the work of Hutton, Cuvier, and Lyell.

Spelling out his ideas in a pamphlet attacking Buckland's new views, Cockburn attributed the formation of the primary rocks to the initial Creation after which primordial waters laid down the secondary rocks. Not much else happened until Noah's Flood, which therefore had to explain the entire fossil record. The bones of giant creatures lay in the oldest strata because these animals were too heavy for the ark and had drowned. Human remains were only found in unconsolidated surface layers and not in rocks because people fled to the highest peaks. There, they drowned some time after animals too confused to flee to higher ground had already become incorporated in flood-deposited sediments. In his rush to condemn Buckland for abandoning Noah's Flood, Cockburn simply dismissed the discoveries and evidence that had convinced the devout Buckland to abandon the idea of Noah's Flood as a geological event. In this way, Cockburn can be viewed as among the first modern creationists.

Several years later, in 1844, Cockburn had an ideal opportunity to challenge Buckland when the British Association for the Advancement of Science met in Cockburn's hometown of York. On the morning of the second day of the meeting, geologists flocked to witness the spectacle of Cockburn challenging their findings of the past forty years. With great composure, the stately Cockburn walked through the crowd and took the stage to stand by the society's president. In a brief presentation he laid out a theory purporting to explain all of geology as the result of a global flood. Cockburn insisted that the world's surface was shaped all at once. Geologists had to explain everything using Noah's Flood, including layered rocks. There had been no extinctions. Rivers did not cut their valleys. After Cockburn sat down and the raucous laughter had died off, Sedgwick rose to deliver a stinging hour-and-a-half response attacking Cockburn's woeful ignorance of geology in remarks characterized by an eyewitness as marked with "a scornful bitterness beyond the power of any reporter to reproduce."[16]

Cockburn was not easily silenced. Immediately after the meeting, he published his address as *The Bible Defended Against the British Association* and challenged Sedgwick to explain Earth's origin and evolution from the beginning to the present day. Opting not to answer at first, Sedgwick eventually wrote Cockburn a short note explaining that the antiquity of the world was demonstrated by unassailable geological evidence. Nothing if not persistent, Cockburn wrote Buckland and Murchison seeking to debate Earth's age. Neither was interested. Meanwhile, Sedgwick had written a long letter to Cockburn explaining his position and requesting the favor of no reply. Ignoring this collective dismissal, Cockburn decided that geologists were just afraid to debate. So he published his ideas as a

New System of Geology in 1849. That his book didn't catch on surprised few but Cockburn.

Buckland was not the only famous geologist to publicly reverse course on the flood. Less than a decade after Adam Sedgwick marshaled geological observations to show how a recent catastrophe reworked Earth's surface and deposited England's surficial gravels, he recanted, in his last presidential address to the Geological Society of London.

> *There is, I think, one great negative conclusion now incontestably established—that the vast masses of diluvial gravel, scattered almost over the surface of the earth, do not belong to one violent and transitory period. . . . We had, in our sacred histories, the record of a general deluge. On this double testimony it was, that we gave a unity to a vast succession of phænomena, not one of which we perfectly comprehended, and under the name diluvium, classed them all together. . . .*
>
> *Our errors were, however, natural, and of the same kind which led many excellent observers of a former century to refer all the secondary formations of geology to the Noachian deluge. Having been myself a believer, and, to the best of my power, a propagator of what I now regard as a philosophic heresy, and having more than once been quoted for opinions I do not now maintain, I think it right, as one of my last acts before I quit this Chair, thus publicly to read my recantation.*[17]

With this spirited reversal, Sedgwick joined Lyell in arguing for disentangling geology from the biblical flood. It was becoming apparent that the stories in Genesis were too short and mysterious to either confirm or challenge geological theories.

In the 1830s the question was not when Noah's Flood occurred but how many grand catastrophes the world had seen. Agreement was growing that there was more to Earth's story than just what the

Bible said. Moses did not lay it all out. Many worlds had come and gone since the dawn of time. Shortly after Buckland's recantation, the Swiss naturalist Louis Agassiz explained the surficial debris and stray boulders of northern Europe. The evidence traditionally interpreted as resulting from a global flood actually recorded the action of glaciers that overran Europe during an age of ice, leaving Noah out in the cold.

By the 1850s, Christian men of science overwhelmingly believed Earth was extremely old. In the decades before Darwin, the failure of a literal interpretation of Genesis to account for earth history helped create new rifts in Christian philosophy. In the spirit of Augustine, many Christians adopted the view that geology could help guide reinterpreting biblical stories. Others, without a background in natural philosophy or geology, came to be known as scriptural geologists. They either considered a literal interpretation of the Bible paramount and geology mistaken or embraced the idea that God just made the world look old, hiding fossils in rocks back at the initial Creation. In this split lay the roots of modern creationism.

Cockburn may have failed to convince the British Association, but he was by no means a lone voice. Scriptural geologists with little to no geological training ignored problematic geological evidence, promoted discredited theories, and invoked exceptions to biblical literalism when it suited their arguments. These forerunners of modern creationists banded together against the coalescing views of ever more geologists who rejected the idea that the Creation and Noah's Flood were all there was to earth history.

Today geologists view all processes as fair game—from slow and steady everyday change to dramatic catastrophes. It's not one or the other, as Lyell and Cockburn both portrayed things. Over the past several centuries, generations of geologists built their ideas on top of preceding theories, disproving or reinforcing what they had heard before. In the process, they learned how everyday change really does

add up to big effects—given time—and that geological catastrophes really did happen, causing mass extinctions not just once but at least five times in the history of the world.

Along the way, the tension over how to read the geologic record—whether as an unimaginably long progression of everyday events or as a series of grand disasters—has characterized the earth sciences. Misunderstanding the nature of this tension caused friction in the relationship between geology and Christianity and still fuels conflict between science and religion.

By the end of the nineteenth century, geologists had disproved a young Earth and a global flood. Archaeologists, however, had begun to unearth ancient flood deposits in the sandy floodplains of Mesopotamia, setting off new arguments for and against evidence thought to record the biblical flood. Their discoveries carried startling implications about the age and origins of the biblical flood story.