1 Major Nineteenth-Century Players

From the standpoint of Catastrophism little progress was made. Uniformity proved a great advance, but in detail it is apt to lead us astray if applied too dogmatically.

– Arthur Holmes, 1913[1]

INTRODUCTION

The most important book on geology published in the nineteenth century was probably *Principles of Geology* by Charles Lyell (in three volumes, 1880–1883), which instigated one of the major scientific debates that raged throughout the nineteenth century – namely that of the catastrophists versus the uniformitarians.[2] The dichotomy set up by these two groups first appeared in a review of volume two of Lyell's *Principles* in 1832.[3] The subtitle to the first edition of the *Principles* elaborates one of the book's main goals: "Being an attempt to explain the former changes of the Earth's surface by reference to causes now in operation." This statement assumed that the physical laws operating today also operated in the past, consistent with the immutability of the laws-of-nature idea – an idea accepted by most philosophers at that time, with the exception of some biblical literalists or scriptural geologists who entertained preternatural causes.[4]

Throughout his book, however, Lyell indicates that not only were the kinds of processes in the past the same as today, but in addition their *intensity* was also the same (see Box 1.1). On this, Lyell received a lot of hostile opposition, especially from geologists who saw evidence in the geologic record of "revolutions" – namely species extinctions, inundations and recessions of the seas indicated by sharp changes in the fossil content of strata, faults that juxtaposed contorted strata with horizontal strata, and mountain-building

BOX 1.1 Extracts from Lyell's Letters[22]

Italics are original. Explanatory notes in square brackets by author.

To Murchison — Naples: Jan. 15, 1829

My dear Murchison, . . . I will tell you fairly that it is at present of no small consequence to me to get a respectable sum for my volume – not only to cover extra expenses for present and future projected campaigns . . . My work is in part written, and all planned . . . it will endeavour to establish the *principle of reasoning* in the science; and all my geology will come in as illustration of my views of those principles, and as evidence strengthening the system necessarily arising out of the admission of such principles, which, as you know, are neither more or less than that *no causes whatever* have from the earliest time to which we can look back, to the present, ever acted, but those *now acting;* and that they never acted with different degrees of energy from that which they now exert. I must go to Germany and learn German geology and the language . . . If I can but earn the wherewith to carry on the war, or rather its *extraordinary* costs, depend upon it I will waste no time in bookmaking for lucre's sake.

To His Sister — Rome: Jan. 21, 1829

My dear Marianne, . . . Longman [a publisher] has paid down 500 guineas [roughly equivalent to 500 pounds sterling] to Mr. Ure of Dublin for a popular work on geology, just coming out [*A New System of Geology*]. It is to prove the Hebrew cosmogony, and that we ought all to be burnt in Smithfield [a site in London used for execution of heretics in earlier times]. So much the better. I have got a rod for the fanatics, from a quarter where they expect it not. The last Pope did positively dare to convoke a congregation and *reverse* all that his predecessors had done against Galileo, and there was only a minority of one against. How these things are so little known in Paris and London, heaven knows.

To Dr. Fleming — June 10, 1829

My dear Sir - . . . Buckland was so amazingly annoyed at my having such an anti-diluvialist paper read [at the Geological Society], that he got Conybeare to write a controversial essay on the Valley of the Thames, in which he drew a comparison between the theory of the Fluvialists, as he terms us, and the Diluvialists, as (God be praised) they call themselves. . . . But you must know that Buckland and Conybeare, distinctly admit three universal deluges, and many catastrophes, as they call them, besides! But more of this when we meet.

events.[5,6] These observations suggested that nature was not uniform in its intensity in the geologic past. Geologists who saw the importance of revolutions and intense, rapid transformations in the rock record came to be known as catastrophists (a term that was probably regarded as an overstatement by many experts of the time). Catastrophists saw that the geologic record was not uniform or cyclic as Lyell and his predecessors Hutton and Playfair had argued.[7] Lyell insisted that, on average, internal processes (e.g., earthquakes and volcanoes) and surficial processes (e.g., rivers, tidal currents, and climate) were of the same intensity globally in the geologic past as they are today.[2] He also applied this uniformity principle to the organic realm, and he rejected the French botanist Jean Lamarck's (1774–1829) proposed theory of biological inheritance, also known as transformation of the species. Lyell's seminal book is essentially a summary of all the known facts about geological processes that operated on the surface of the Earth throughout recorded human history (the past few thousand years), and asserts that these processes alone are sufficient to explain the past geologic record going back millions of years; catastrophic events or revolutions were not required. Remarkably, with the exception of parts of the third volume, there is very little actual geology in *Principles*. Its main emphasis is on the historical record.

The second controversy at this time was that of the Neptunists (whose chief proponent was Abraham Werner, together with his students) and that of the Plutonists (whose chief proponent was James Hutton, (popularized by John Playfair). The Neptunists thought all rocks were precipitated from a global ocean, including igneous rocks. The Plutonists, on the other hand, recognized igneous rocks for what they were, namely, derived from magma. The two controversies are somewhat intertwined: uniformitarians were generally Plutonists, and catastrophists were generally Neptunists. That Neptunists were also catastrophists is hardly surprising since they required a global menstruum, or primeval ocean from which all rocks were precipitated, and this ocean advanced and receded globally more than once

Table 1.1 *Principal nineteenth-century players*

Name	Lifespan	Training	U/C	Age in 1830*
Hutton, James	1726–1797	Medicine	U	–
Werner, Abraham	1749–1817	Mining/mineralogy	C	–
Cuvier, Georges	1769–1832	Natural history	C	61
Smith, William	1769–1839	Surveyor	?	61
Buckland, William	1784–1856	Theology	C	46
Sedgwick, Adam	1785–1873	Theology/math	C	45
Conybeare, William	1787–1857	Theology	C	43
Murchison, Roderick	1792–1871	Military	C	38
Lyell, Charles	1797–1875	Law	U	33
Agassiz, Louis	1807–1873	Medicine	C	23
Darwin, Charles	1809–1882	Medicine/theology	U	21

Note: U: uniformitarian; C: catastrophist; * the year *Principles* was first published.

during major Earth revolutions. That uniformitarians were generally also Plutonists is something of a historical accident reflecting the fact that Hutton saw igneous activity as causing rejuvenation of the landscape after being denuded by uniform erosional processes operating today.[8] The Neptunism–Plutonism controversy is addressed in more detail in Chapter 4 in the context of the origin of igneous rocks.

The purpose of this chapter is to introduce the reader to the main players active in these debates by providing a brief biographical sketch for each author followed by some comments on their historical role; some of these authors will be encountered again in subsequent chapters. Table 1.1 summarizes the players chronologically, in order of their date of birth. Due to space constraints, the list is highly selective.

Their educational training and their age at the time *Principles* was first published is also shown, in order to provide some historical context. Whether they were uniformitarians or catastrophists is also noted. The nineteenth century was one of the most scientifically active centuries for the nascent disciplines of geology and paleontology. The first three authors (Hutton, Werner, and Cuvier) largely belong to the late eighteenth century, but their views had a strong influence on nineteenth-century debates and remain important to this day.

James Hutton (1726–1797). James Hutton was born in Edinburgh, and his father, a wealthy merchant, died when he was three.[9] He inherited property and enough wealth that he did not have to earn a living. He entered the University of Edinburgh in 1740 to study the humanities; he reentered the university again in 1744 to study medicine. He spent two years in Paris beginning in 1747, where he developed his interest in chemistry and geology. He received a medical degree from the University of Leiden in the Netherlands in 1749, but he never practiced medicine. In 1750 he retired to Edinburgh where he took up farming on his inherited property southeast of the city. He also engaged with a friend in a successful business involving the manufacture of ammonium chloride (referred to as *sal ammoniac* at the time), which was used in industrial processes and probably added to his wealth. In 1754 he traveled widely in northern Europe to study farming methods, and also developed his increasing interest in geology. After fourteen years of farming, he moved to Edinburgh in 1768 where it appears he undertook experiments in chemistry and also collected fossils. (At the time the word fossil included both minerals and organic remains.) He became an active member in what would become the Royal Society of Edinburgh in 1783. He was friends with members of the Scottish Enlightenment, including the political economist Adam Smith, the chemist Joseph Black (who discovered CO_2), James Watt (of steam engine fame), James Hall (who did some of the first experiments in geology), and the mathematician who would eventually become his biographer, John Playfair.

Hutton presented his paper *Concerning the Systems of the Earth* to the Geological Society in 1785, which was then published in 1788 as *Theory of the Earth.*[8] This paper also formed volume one of his two-volume *Theory of the Earth, with Proofs and Illustrations*, published in 1795.[9] Because of Hutton's obtuse prose (Steven Jay Gould, evolutionary biologist and historian, said he was a "lousy" writer),[10] this book received little attention except from opponents who supported Abraham Werner's views. Hutton's views were popularized by his friend John Playfair in *Illustrations of the Huttonian Theory of the Earth,* published in readable prose in 1802, after Hutton's death.[7]

At the beginning of his 1788 paper, Hutton viewed the globe as a machine constructed on chemical and physical principles with the purpose to support animals and humans. He recognized the solid earth, the seas, and the atmosphere as being interconnected: "it is in the manner in which these constituent bodies are adjusted to one another and the laws of action by which they are maintained in their proper qualities and respective departments that form the theory of the machine we are now to examine."[8] This statement is a remarkably modern form of what is now termed Earth System Science, a perspective that emphasizes the interdisciplinary nature of the Earth Sciences.[11] Only von Humboldt in his *Cosmos* (1856) came close to such a modern position.[12]

Hutton is best known, however, as the chief proponent of the Plutonist or Vulcanist school, whereby denudation (erosion) eventually reduces the continents to sea level and ocean sediments are rejuvenated back onto the continents by igneous activity at depth, but exactly how igneous activity caused rejuvenation was not ventured into.[9] How fossiliferous oceanic sediments were lofted onto mountain tops persisted as the single most important geological puzzle well into the late twentieth century (see Chapter 5).

Hutton recognized the importance of unconformities as reflecting deformation and folding of sediments followed by erosion and renewed deposition in a cyclic fashion (Figure 1.1). Hutton's overall view was that the Earth's history was cyclic (or repetitious) rather than historical (or progressive), and for this view he has been criticized.[10] In defense of Hutton, it should be pointed out that the geologic timescale had not yet been established at the time he was

FIGURE 1.1 Hutton's unconformity on Arran Island, western Scotland. Devonian Old Red Sandstone dipping moderately to the right overlies steeply dipping Dalradian (late-Precambrian) schist. Hutton visited the site in 1787.

writing, so the idea that geology would become a historical science did not yet exist. Hutton also recognized granite as an intrusive igneous rock, commonly younger than the surrounding rocks.[13] At the time, igneous rocks were called "primitive" rocks by the Neptunists and thought to be the oldest rocks of all.

The most quoted sentence from Hutton's work is the last sentence of his 1788 paper: "There is no vestige of a beginning and no prospect of an end." This was interpreted to imply there was no creation, which drew accusations of atheism from colleagues.[14] Possibly, for insurance against such attacks, Hutton peppered his text with statements such as "Devine Wisdom" and "work of infinite power and wisdom." Having spent two years in Paris, the religious views of Hutton, although not known, may have been similar to his more irreligious Enlightenment colleagues on the continent.

Abraham Werner (1749–1817). Born in Saxony, in eastern Germany, to a family with a long history in mining, Abraham Werner received his first formal education from his father who encouraged his interest in mineralogy.[16] After schooling, he took a position in his father's iron foundry. He decided to study mineralogy and mining as a career at the mining school of Freiburg, and then went on to Leipzig University, where he also studied law. In 1774, he published a paper entitled "On the External Characteristics of Fossils," a paper entirely focused on mineralogy rather than biological fossils as the word would come to be defined. In 1775, he was offered a position as a teacher at the School of Mines at Freiberg where he remained for more than forty years. Werner was methodical and orderly, but he did not take to writing. In fact, he published less as he got older – his ideas and subsequent fame were spread chiefly by word of mouth of his students.[16,17]

Werner was very popular as a teacher and eventually he drew students from across Europe to study his "geognosy," as he called geology. His famous students include Robert Jameson (1774–1854), later to become professor at Edinburgh; the polymath explorer Alexander von Humboldt (1769–1859); and Leopold von Buch (1774–1853), the Alpine geologist. Werner and his students were the chief proponents of the Neptunist school, in which all rocks were thought to be derived from a primeval global ocean through chemical precipitation (e.g., salt, gypsum, and limestone) or physical precipitation (e.g., shales, sandstones, and graywackes), including the igneous rocks (basalt and granite) as well. Eventually, even many of his own students saw that Werner's Neptunism was invalid on a global scale, and they gradually accepted the Plutonist school concept that igneous rocks formed from molten rocks (fusion), as Hutton had long maintained. Archibald Geike noted in his 1905 book that Werner made important contributions to mineralogy, but he was "disastrous to the higher interests of geology."[17] Lyell was equally unimpressed, saying in his *Principles*: "Werner's theory was original, but it was extremely erroneous." On the other hand, a glowing review of Werner's legacy can be found in the *Complete Dictionary of Scientific Biography*.[15] The Neptunist–Plutonist controversy is outlined in more detail in Chapter 4.

Georges Cuvier (1769–1832). Born in France, Cuvier was one of Europe's most influential scientists of his day in the fields of zoology, paleontology, and geology.[18] He held the chair of comparative anatomy at the French National Museum of Natural History, Paris. Historically, he was on the losing side of two important eighteenth- and nineteenth-century controversies: the transformation of one species to another (first championed by Lamarck and later by Darwin) and his catastrophist view of geologic biohistory.[18] He developed the fields of comparative anatomy and biological classification and is credited with the first report on extinctions. His ability to identify different species from fossil bones was unmatched in Europe. His studies of modern organisms and of fossils led him to conclude that many fossil species represented ancient life and were extinct. For example, he recognized, through detailed anatomical comparison, that the Indian and African elephants were different species, and that the bones of these modern elephants were different from the fossil bones of the woolly mammoth and mastodons, which were both extinct. Extinction at the time was thought to be impossible because "Almighty Wisdom" would not permit organisms that had been divinely created to die out. Human fossils had not yet been recognized in the diluvial (glacial) sediments to Cuvier's satisfaction, so in his view, extinctions were not attributable to hunting by mankind. Whether the woolly mammoth became extinct during the Pleistocene epoch due to overhunting or climate change is still debated today.[19] His recognition of extinctions led him to a catastrophist view of Earth's biohistory.

Cuvier was mainly a "cabinet" scientist who built a world-class collection of museum specimens, but he was less aware of the rapid developments taking place in geology at the time, particularly in stratigraphy and the work of William Smith (1769–1839) in England.[17] He augmented his museum collection by asking "savants and amateurs"[18] to submit fossil specimens to him, and in return he would identify them, which produced a tremendous response from the international community. His important work with Alexandre Brongniart, his colleague at the Paris museum, on the Paris basin sediments and their fossils was one of his few field-based publications.[20]

His most important work *Recherches sur les ossemens fossiles* (*Researches on Fossil Bones*) was published in four volumes in 1812. The first volume, which was written last, is known as *Discours Préliminaire* and was written for a general audience as a preface to the subsequent and more academic volumes, and became a very popular book translated into several European languages.[21] He recognized several different extinction events ("revolutions" in Earth history), but he thought the most recent extinction event occurred about 6,000 years ago and corresponded to the so-called diluvial deposits (now known to be glacial in origin), associated at the time with the biblical flood. There is no evidence, however, in his *Discours* that he was a biblical literalist, which in any case would have been highly unusual for a French Enlightenment scientist. He emphasized that processes operating today were insufficient to cause his "Earth revolutions," which was clearly a swipe at Hutton and Playfair before him, both of whom he referenced in his *Discours*. Cuvier died a few years after Lyell's *Principles* were published.

Cuvier was a gifted writer and illustrator, and a highly organized scientist. Lyell, after visiting Cuvier at his Paris museum, in a letter to his sister Marianne, marveled at Cuvier's efficient organization and work habits, noting that when Cuvier was working on a manuscript he placed all references on that topic in a single room so that he had everything at hand.[22] Lyell also notes that Cuvier's assistants "save him every mechanical labor, find references et cetera, are rarely admitted to his study, receive orders and speak not." (see Box 1.1) According to Lyell, Cuvier's library was also perfectly ordered according to zoological subject. Cuvier's intellectual heft gave substantial weight to the catastrophist school of thought, especially with regard to species extinctions.

William Smith (1769–1839). William Smith was born in the village of Churchill, Oxfordshire, in southeast England. His father, who died when William was seven, was the village blacksmith.[23]