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ISBN 978-3-319-64951-1 ISBN 978-3-319-64952-8 (eBook)
DOI 10.1007/978-3-319-64952-8

Library of Congress Control Number: 2017950127

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Historians of science acknowledge that the late eighteenth through mid-nineteenth centuries represent a pivotal era in the evolution of the geological sciences, in which geology became a bona fide and well-established scientific endeavor. At the same time, science was increasingly brought into the public eye, largely thanks to public demonstrations and lectures aimed at nonspecialists, at both professional institutions (such as the Royal Institution in London) and more informal ones (including the Lyceum movement in the USA). The availability of what would now be termed *free-choice learning opportunities* at the popular level opened up science to a significant new audience, women as well as men without formal education in the sciences. The education of children was also undergoing substantive changes, including the formation of girls' schools (at both the elementary and secondary levels), providing parents with options beyond private tutors and home schooling. But teachers, tutors, and homeschooling mothers needed to learn both the science of the day and effective pedagogies that could be used to make science both understandable and appealing to children.

This was also the heyday of the literary style known as the *familiar format*, books written largely *by* women *for* women and children in the form of letters, conversations, and catechisms. These works were commonly set in a domestic setting and featured children (both boys and girls) actively exploring the natural world through hands-on activities, experiments, and direct observations, guided by a patient and knowledgeable mother figure. This style of science popularization played a central role in both formal and informal science education during the same time period that geology was becoming a well-defined science. It is therefore surprising that a study of women's popular-level geological writing during this period has not yet been published. This work endeavors to fill some of that gap in our understanding of the role of woman popularizers, specifically those utilizing the familiar format, in shaping public understanding of geology in the first half of the nineteenth century.

Chapter 1 begins by surveying the status of geology in the early nineteenth century, including debates over terminology, physical processes, theology, and the accepted role of women. After introducing some of the longstanding political issues with the popularization of science in general, the bulk of Chap. 2 focuses on the birth of the familiar format and illustrates the wide diversity of works that fall under its umbrella. Chapters 3–8 form the core of this volume, analyzing the lives, literature, and resulting lessons of six women who authored familiar format geological science books—Jane Marcet, Delvalle Lowry, and Maria Hack (Europeans) and Jane Kilby Welsh, Delia Woodruff Godding, and Almira Hart Lincoln Phelps (Americans). While these authors often found some level of fame in their lifetime, they have largely been forgotten today. This work is a first step toward righting that wrong.

Due attention will then be paid in Chap. 9 to three examples of women popularizers of geosciences during this era who elected not to write in the familiar format—Mary Roberts, Rosina Zornlin, and Mary Somerville—situating them in contrast to their colleagues. Finally, Chap. 10 explores the societal factors that led the familiar format to, metaphorically, go the way of the dinosaur, through the lives and writings of three women who, in their own ways, negotiated this transition to a more modern (and presumed to be more masculine) style of popularizing science: Arabella Buckley, Agnes Giberne, and Lady Grace Anne Prestwich.

This is the story of uncommon women who persevered in the face of a society that severely curtailed their access to formal education and male critics and rivals who alternately praised and ridiculed their popular level writing. These women persevered despite personal adversity, financial uncertainty, and onerous familial responsibilities, and at a time when the very science they were attempting to encapsulate was in the midst of seismic shifts of its own. They breathed life into the sometimes stiff and staid story of rocks and geological strata, and not only educated generations of children, but encouraged woman and men, young and old, beginner and practitioner, to think more deeply about the planet on which we all live. This book is an attempt to repay a portion of the debt that prior generations of children, and adults, owe to these women who persevered.

New Britain, CT Kristine Larsen

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Chapter 1
The Status of the Geological Sciences Circa 1800

1.1 Debating Definitions

In her 1852 volume *Outlines of Geology for Families and Schools*, Rosina Zornlin explains that "Geology consists of an inquiry into the structure of the earth, and the nature and arrangement of the materials of which it is composed" (Zornlin 1852: 1). Such a definition would not seem out of place in a similar volume today, with the caveat that it does not mention the processes that shape the earth. However, it is important to note that geology as a science had undergone an, at times, particularly difficult and painful birthing process between 1780 and 1830, one rife with tensions between science and religion as well as sometimes vociferous political debates between different theoretical schools (Laudan 1987). It is also important to understand that the fundamental vocabulary by which geology and other sciences are described today was not universally agreed upon in the first half of the nineteenth century. For example, before 1900 the term *natural history* roughly covered what today would include the biological and geological sciences, while *natural philosophy* encompassed the topics of physics and chemistry. It is also essential to recognize that not only was geological knowledge limited at the turn of the nineteenth century, but also the general understanding of chemistry and physics. For example, less than 40 chemical elements had been observed in nature by 1800. Dalton's atomic theory of matter debuted in the first decade of that century, but Maxwell's unified theory of electromagnetism would have to wait another five decades to be codified, and radioactivity only entered the scientific imagination in the last decade of the nineteenth century.

The term *mineral*, which today refers very specifically to the naturally found chemical compounds that form the components of rocks, was once used far more broadly, as one of the three kingdoms of nature (animal, mineral, vegetable). Therefore in the late eighteenth and early nineteenth centuries *mineralogy* was the general umbrella term under which one could find not only the study of modern minerals, but rocks and fossils as well. Mineralogy was also, by necessity, intimately

K. Larsen, *The Women Who Popularized Geology in the 19th Century*,
DOI 10.1007/978-3-319-64952-8_1

connected to chemistry, and one could find a great deal of chemical knowledge contained within mineralogy texts. By the 1790s specific subdisciplines with a narrower focus emerged in the writings of Abraham Gottlob Werner (1749–1817) and were commonly used by fellow German scientists for the next three decades. These included *oryctognosy* (the identification and classification of minerals), *mineral geography* (the geographical distribution of rocks and minerals), *economic mineralogy* (the uses of minerals by and benefits to human society), *chemical mineralogy* (the chemical analysis and composition of minerals), and *geognosy* (the description of rock formations and their relationships to each other) (Guntau 2009). This last term derives from the invented term g*eognosie*, or *earth-knowledge*.

All of these were very practical, observation-based modes of science, and largely avoided theoretical considerations. There was also (as previously noted), a decided lack of attention to geological processes in this classification scheme. These terms were also not universally utilized, especially beyond Germany. Such controversies concerning terminology often made their way into the popular-level writings and book reviews of the day. For example, in her *Conversations on Mineralogy* (1822), Delvalle Lowry's young character Frances asks about the difference between mineralogy and geology. Her tutor, Mrs. L, explains

> Mineralogy, in its most extensive signification, is the science of the unorganized mass of the globe; in which sense, it is divided into *Oryctognosy*, or a knowledge of minerals by their external characters; *Chemical mineralogy*, which teaches us to distinguish them by a knowledge of their composition; and *Geology* (or Geognosy), which makes us acquainted with the different relations of the mineral masses, which compose what is termed the *crust of the earth*. (Lowry 1822: 15–6; emphasis original)

She later notes that Oryctognosy is described as "the alphabet of geology" (Lowry 1822: 16). In contrast, a review of the book in *The Quarterly Journal* (1823, 155) criticizes this terminology, offering that "There is more parade than profit in this distinction. Mineralogy and geology are quite sufficient without oryctognosy—a lately introduced and bad term." Similarly, in her 1833 work *Familiar Lessons in Mineralogy and Geology*, Jane Kilby Welsh's Mr. G explains to his family that "'The term Geology… is significant of the science of the earth, and is derived from the Greek for *earth* and *reason*. Werner, and some of the French authors, term it Geognosy; but the former appellation is the most generally received at the present time" (Welsh 1833: 11). Mr. G then further notes that there is an additional area of study, "an inquiry into the nature of those causes which have operated to produce its present state, and which may be designated as *Secondary Geology*" (Welsh 1833: 11). We see reflected here what became two important distinctions in geology (and which today are often represented in two different types of courses in the introductory undergraduate geology curriculum): *historical geology*, concerned with reconstructing the geological past history of the earth from its formation to the present day, and *physical geology*, a study of the processes that shape the earth, both in the past and the present (Laudan 1987).

The practitioners of geognosy, the careful observers of geological formations, realized that there were distinctive layers in rock formations that, although clearly different from each other, were reproducible in general properties from one geographic area to another, especially in the order in which these layers could be found. By 1830 four such divisions—termed *primary* or *primative*, *transition*, *secondary*, and *tertiary*—were commonly referred to in the geological literature. Two other types of rock formations were also identified, layers of rock deposits termed the *diluvium* and *alluvium*, the former in particular becoming controversial in that it hinted at potentially chaotic and catastrophic events. By the mid-1800s, many of the names associated with the modern geological time scale, including Silurian, Cambrian, and Carboniferous, came to be associated with distinct layers found in the rock record, as seen in Fig. 1.1 (Gregory 1921).

But the identification of these layers, and a chronological reconstruction of the earth's history, did not depend on the rocks alone. *Paleontology*, the study of the fossil

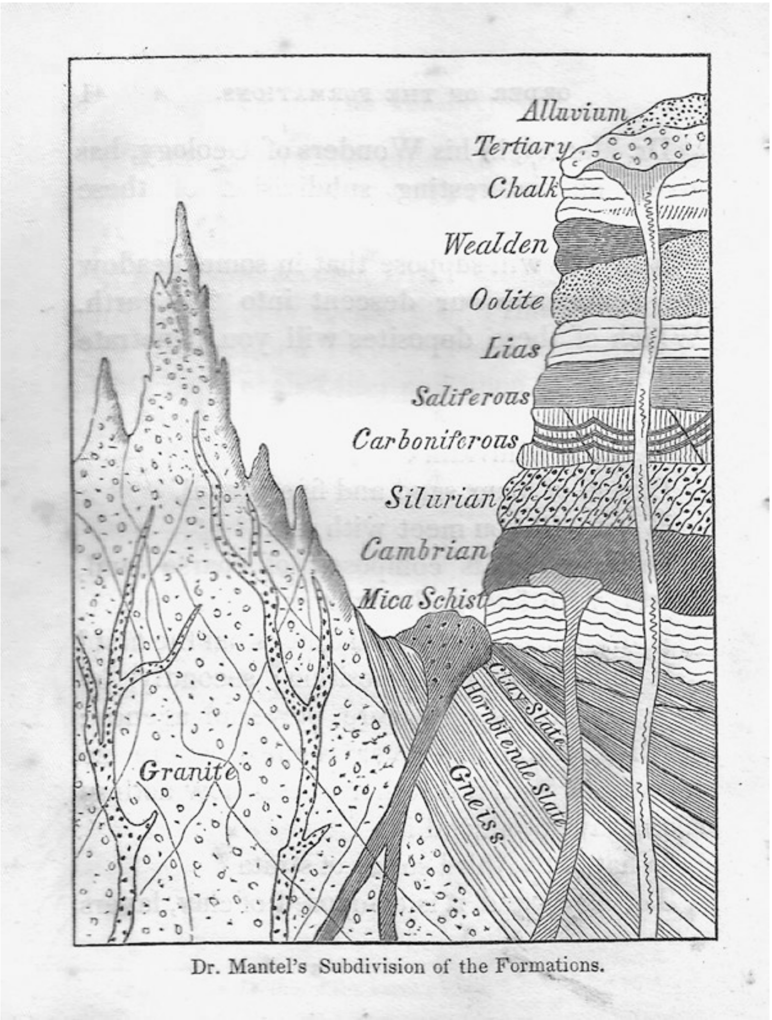

Fig. 1.1 Stratigraphic column. Reproduced from Delia W. Godding (1847) *First Lessons in Geology*

record, and a particular subdiscipline *Conchology*, the study of fossilized mollusk shells, also played a central role. It was therefore common for geology texts in the early 1800s to integrate these subjects within the larger discussion of the history of the earth.

It was also during this time that the relationship between geology and geography was being negotiated, especially as it involved the obvious overlap between the two fields, as they could both lay claim to a study of the surface of the planet. In her *First Lessons in Geology*, Delia Woodruff Godding defines geology as "a science which treats of the earth's structure, and of the substances which compose it" and differentiates it from geography, which "tells how the earth is divided into oceans and continents, mountains, plains, vallies [sic], &c., and what their names are; but Geology tells *how* and of *what* they are made" (Godding 1847: 9–10). But as noted in the influential work *Universal Geography* (1824), "The surface and soil of a country, the nature of its waters, and to some extent, its climate and salubrity, *depend on its geological structure.* Without attention to this subject therefore, our knowledge of geography would be incomplete" (Woodbridge and Willard 1824: 16; emphasis original). Woodbridge and Willard divide geography into three branches:

> Physical Geography is a description of the structure and natural history of the earth, including its natural divisions, climates, and productions.
>
> Political, or Moral Geography, is a description of the state of men in society, including an account of their religion, government, knowledge, and arts.
>
> Statistical Geography is a description of states and empires, with their extent, population, and resources. (1824: 1)

Physical geography, or *physiography*, is defined by Grace Anne Prestwich in her 1883 essay "The Face of the Globe" as "a science lying midway between geology and geography, and partaking of the nature of both, to account for all these diversities of surface, and to investigate the causes which have led to the present configuration of the globe" (Prestwich 1901: 201–2). Rosina Zornlin compares geology to ancient history and physical geography to modern history, or "Geology, or the Earth in its former condition; and Physical Geography, or the Earth as it is" (1839: 2). As physical geography clearly has a geological component to it, it will be included as a geological science in this volume.

But definitions were not the only areas of difficulty within the geological community; classification systems were also plagued with politics. Nowhere was this perhaps more clearly evident than in the study of minerals. The collecting of minerals and fossils was a popular hobby in the eighteenth and nineteenth centuries, whereby collectors would display their collections in what became known as the *natural history cabinet*. But such collections were not only considered works of art, they were works of science as well, and as such, it became increasingly important that the cabinets reflected some scientific, standardized classification system (Greene and Burke 1978; Simon 2002). Just as Carolus Linnaeus had classified plants and animals by their external characteristics, minerals as well had obvious visible properties, including color and, in the case of crystals, their shapes. There was also reason to classify minerals by their chemical composition. Technology utilized in the early 1800s, especially the *blowpipe* and *goniometer*, greatly aided both the analysis of crystals and determining a mineral's chemical composition.

At its most basic, a blowpipe is a thin tube into which a person blows, directing air over a flame, thereby increasing the temperature and intensity of the flame. A small amount of a mineral is subjected to this flame, and the color of the flame, as well as whether or not the mineral sample melts or fuses in the temporarily increased heat of the flame (or any other noticeable reaction) are properties used to identify the mineral (Newcomb 2009).

The simplest goniometers (instruments that measures the angles at which the planes of a mineral's crystals meet) are little more than glorified protractors, as shown in Fig. 1.2. In 1809 William Wollaston (1766–1828) developed an improved technology that was both more precise and accurate, in which reflections from the mineral's crystal planes are observed in order to measure the angles. This *reflective goniometer* was considered at the time to be "of the highest value to Crystallography" but there was "an opinion of its use being attended with some difficulty" (Brooke 1823: 27) In response, numerous books on the subject included detailed instructions in order to make this vital technology more widely used.

But while both crystals and chemical composition could be analyzed, they often gave conflicting suggestions as to how to classify minerals. Minerals with similar crystalline forms may have very different chemical compositions, while chemically identical minerals might manifest different crystalline forms. There resulted various schools of thought as to how to best deal with this complex situation. Crystallographer René Just Haüy (1743–1822), himself an amateur botanist, advocated a decidedly

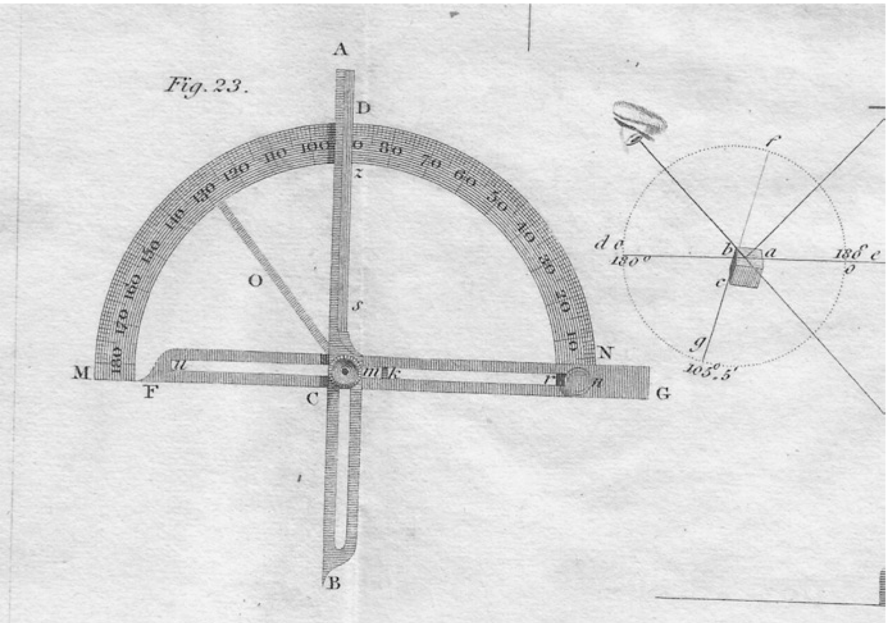

Fig. 1.2 Goniometer. Reproduced from Delvalle Lowry (1822) *Conversations on Mineralogy,* Amer. Ed

Linnaean system, where minerals were divided into four classes, the acidiferous, earthy, nonmetallic, and metallic substances. Despite the fact that his classification was heavily dependent on crystalline forms, these classes also incorporated chemical analysis. In contrast, Abraham Werner's system utilized external, directly observable characteristics (Greene and Burke 1978). Similarly, although Werner's system relied on observable external properties in identifying a mineral, he also admitted that chemical properties were important in mineral classification (Laudan 1987). It is therefore not surprising that some authors of geology textbooks and popularizations developed their own systems of classifying minerals, for example Delvalle Lowry in her *Conversations on Mineralogy.*

Another important area in which the geology of the nineteenth century differed from that of today is the modern distinction between amateur and professional (and the hierarchical value judgment these terms generally imply). Given the fact that geology was not widely taught in universities, most practicing geologists were self-taught (or were taught through attending public rather than formal university lectures). Similarly, paying positions at universities were uncommon; geology was rather an avocation than a vocation, and most geologists had to support themselves through writing, lecturing, fossil and mineral hunting, family fortunes, or other means. For example, Sir Charles Lyell himself only held a professorship in geology (at King's College) from 1831 to 1833. A modern delineation between professional (university-trained) and amateur (self-taught) began to develop gradually, and a true demarcation became established only around the time of World War I (O'Connor and Meadows 1976).

Finally, it must be noted that the term *scientist* itself was not widely in use through most of the nineteenth century. Commonly used terms instead included *natural philosopher* or *man of science*. The genesis of the term scientist is generally credited to William Whewell's 1834 review of Mary Somerville's *On the Connexion of the Sciences*. After noting that there is no "name by which we can designate the students of the knowledge of the material world collectively," Whewell (1794–1866) describes a meeting of the British Association for the Advancement of Science at which

> some ingenious gentleman proposed that, by analogy with artist, they might form scientist, and added that there could be no scruple in making free with this termination when we have such words as sciolist, economist, and atheist—but this was not generally palatable. (Whewell 1834: 59)

In his outgoing presidential address before the American Astronomical Society, Benjamin Apthorp Gould (1824–96) also lamented that

> By an unhappy, though perhaps natural, mischance, the English language has had no name for the scientific investigator, nor word to denote his calling….Therefore it was, that twenty years ago I ventured to propose one, which has been slowly finding its way to general adoption; and the word scientist, though scarcely euphonious, has gradually assumed its place in our vocabulary. (Gould 1869: 9)

Thus the nineteenth century was a pivotal yet volatile era in the history of geology, where even individual words themselves were disputed. But the disagreements between geologists concerning scientific vocabulary and the classification of minerals were just the tip of the iceberg in terms of scientific disputes in this rapidly evolving science. Complicating the geological debates of the time (including the nature of the forces behind the creation of large-scale geological features and the different types of rocks) was the fact that religion, not only empirical science, was often behind some of the proposals.

1.2 The Neptunism/Plutonism Debate and the Role of Religion in European Geology

The late eighteenth and early nineteenth centuries featured a series of passionately debated rival hypotheses as geologists attempted to interpret and explain the rock samples and geological structures they increasingly collected and studied. At the same time, the vast majority of these same scientists were practicing Christians, and the growing number of apparent disparities between the literal word of the Scriptures and the observed properties of the natural world provided a source of tension for both individual geologists, and for geologists and theologians in general. At the two extremes were those who felt that science owed nothing to religion in the search for truth, and those who believed that the literal and infallible Word of God always trumped the observations and hypotheses of the limited human mind. In the middle were the vast majority of geologists, who sought to discover the laws of the natural world (laws that they still believed ultimately derived from God), no matter how contrary these laws might appear to a literal reading of the Bible, or who strived to either find agreement between a more liberal interpretation of the Bible and the observations of geology or used geology in an attempt to prove the truth of events within the Bible. The situation was so volatile that an anonymous book reviewer lamented in 1832 that "Enveloped in visionary theories, the formation of the earth remained a mystery only to be speculated upon by the learned; whist the absurd notion, that all natural truth was contained in the volume of revealed religion, checked inquiry and forbade investigation" (*The Athenaeum* 1832: 77).

The first important scientific debate centered around whether water or fire was the main driving force behind geological activity. In the 1780s Abraham Werner interpreted the vast layers of rock called geological strata as being the result of an original primeval ocean that had covered the infant earth. In his hypothesis separate layers of different rock types formed in sequence as materials of different varieties were deposited one on top of the other. He therefore posited that over time deposition and chemical precipitation were responsible for all types of rocks. His model became known as the *Neptunist hypothesis* and was quickly embraced by a number of deeply religious geologists, in part because it appeared to parallel the Biblical account of the great Noachian Flood. However, basalt and similar rocks were found to be associated with volcanic features, which supported a rival hypothesis that posited that the earth's internal heat and the resulting melting of rocks drove geologic processes (the so-called *Vulcanist hypothesis*).

In his seminal 1788 treatise *Theory of the Earth*, Scottish geologist James Hutton (1726–1797) greatly extended the Vulcanist hypothesis to include the idea that, while some rocks were laid down by water, both heat and pressure from the interior of the earth uplifted and deformed the strata, creating many of the large-scale geological structures found in the environment (such as mountains). Hutton's model is therefore sometimes termed the *Plutonist hypothesis*, although in many nineteenth century texts the term Vulcanist is used synonymously (Hallam 1989). In addition, Hutton posited that the processes that formed geological structures in the past are precisely those that are still observed to modify the surface today. No supernatural events are required to either create mountains nor wear them away, only the slow, relentless working of physical processes. Not only was the Hand of God seemingly removed from the face of the earth in Hutton's model, but there was another serious problem for Biblical literalists: in order to explain the geological structures seen today, these slow processes required millions of years (or longer) to shape our planet, not the 6000 years of the Mosaic chronology. Also problematic in Hutton's *steady-state* or *uniformitarian model* was that there was no direction in the geological evolution of the earth. Endless cycles modified rocks and rock formations without apparent plan or design. "I can find no traces of a beginning, no prospect of an end," Hutton explained, in a seminal quote highlighted by Charles Lyell in his *Principles of Geology* (Lyell 1830: 63).

There was a backlash unleashed upon Hutton, along with charges of blasphemy and atheism. Richard Kirwan (1733–1812), chemist, mineralogist and President of the Royal Irish Academy, was one of Hutton's most vociferous public critics, and in the introduction to his *Geological Essays* (1799) argued that "*sound* geology *graduated* into religion, and was required to dispel certain systems of atheism or infidelity, of which they had had recent experience" (qtd. in Lyell 1830: 68; emphasis original). Geologists leaning toward a more literal interpretation of the Bible not only embraced Werner's Neptunist model for its emphasis on a directional progression of creation and the effects of worldwide floods, but bolstered it with their interpretation of the results of the rock and fossil studies of French anatomist and zoologist Baron Georges Cuvier (1769–1832).

Cuvier had spent many years studying fossil vertebrates, especially fish, and published a series of papers in the *Annales du Muséum*. Upon completing this work in 1810, he turned to synthesizing the results of his research and interpreting what he felt the evidence in the fossil record implied for the history of the earth. His 1812 work *Ossemens Fossiles* contained his earlier papers on fossil fish, and was also prefaced by an essay, *Discours Préliminaire* (Preliminary Discourse), that was later reprinted on its own as *Discours sur les Révolutions de la Surface du Globe* (Discourse on the Revolutions of the Surface of the Globe). Since delicate fossils were often found intact, Cuvier reasoned that they must have formed in situ relative to where the organism had died. But the fossil record demonstrated that there had been a series of widespread changes in the fossil types. Since Cuvier did not find evidence of intermediate or transitionary forms between the organisms in successive strata, he interpreted the fossil record as evidence that the planet had suffered a series of widespread (but, importantly, not necessarily worldwide) catastrophic flooding events. In the hypothesis known as *Catastrophism*, all life became extinct with the end of each geological catastrophe, and new forms of life were generated afterwards. Cuvier himself did not offer a model for the creation of these new species, but it is known that he was not a supporter of Lamarckian evolution (Hallam 1989; Rudwick 1997).

Nor did Cuvier invoke a religious explanation, despite the co-opting of his scientific ideas by a segment of the geological community in order to bolster a literalist interpretation of the Book of Genesis. The first problem was that Cuvier had not insisted on worldwide catastrophes (in conflict with the story of Noah); the second was that Cuvier had a reputation for being a religious skeptic. While he mentioned the Noachian Flood in his popular lectures, biographer Martin Rudwick argues that it was a tactic used to proactively defend his science against any accusations from Biblical literalists (Rudwick 1997).

The misleading association between Cuvier's work and Scriptural literalism is due in large part to the English translation of *Discours Préliminaire* by University of Edinburgh Professor of Natural History and founder of the Wernerian Society Robert Jameson (1774–1854). In what he renamed *Essay on the Theory of the Earth* (1813), Jameson made it clear in his preface and editorial notes that he believed that Cuvier had provided incontrovertible scientific evidence in support of a historical Noachian Flood. This interpretation was embraced by many of his readers, including some of the more religious British geologists (who, coincidentally, were also members of the clergy). This gave birth to the *Diluvianist movement*, a coterie of geologists who attempted to use the diluvial layer of the fossil and rock record to provide scientific evidence in support of not only the Biblical Deluge, but the entire Book of Genesis (Hallam 1989). The Catastrophist movement in general was also widely supported by religious literalists, as the genesis of new species after each catastrophe was seen to only be possible through a special creation by God.

One of the most widely respected, read, and cited diluvianists was William Buckland (1784–1856), originally Reader of Mineralogy at the University of Oxford. When he became Reader of Geology in 1819, his inaugural lecture (published as *Vindiciae Geologicae; or, the Connexion of Geology with Religion* [1820]) was "an attempt to shew [sic] that the study of geology has a tendency to confirm the evidences of natural religion; and that the facts developed by it are consistent with the accounts of the creation and deluge recorded in the Mosaic writings" (Buckland 1820: ii). As with other scientific works of his time, Buckland took the occasion to point out that the distribution of minerals and other niceties of the natural landscape were evidence of the benevolence and design of God, and argued against materialism by affirming that even though geological processes work via the natural laws God Himself set out, they still require the continual Hand of God to control and direct the occasional current-day catastrophe according to His design and plan (Buckland 1820). Buckland then sets out his central argument, including the following points:

1. The oldest rocks have no visible fossils; therefore life had a definite beginning, which was accomplished by the Hand of God.
2. The diluvial layers provide "so decisive and incontrovertible" evidence of a worldwide flood 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 … at a period not more ancient than that announced in the Book of Genesis" (Buckland 1820: 23–4).

But in order to successfully align geology with a Biblical interpretation, Buckland had to work out apparent contradictions as well as caution against common improper interpretations of the geological record. Most common of these was the interpretation of the fossil seashell-laden layers found on mountains as evidence of the Mosaic flood. The most obvious apparent contradiction between geology and theology, the short time frame contained in the Mosaic history, could be overcome by a variety of methods that involve reinterpretations of Scripture. These include the insertion of a gap of time between the beginning of the world and the six days of creation (i.e. between verses 1 and 2 of the Book of Genesis) or the interpretation of the six days of creation as far longer periods of time. It became common in the literature to refer to the six days as "six successive epochs of indefinite duration" (Bakewell 1828: 26), thus providing sufficient time for natural geological processes ranging from catastrophes to the gradual erosion of rivers to create all structures that were formed before the Great Flood. A third possibility is that there was a long period of time between God shaping the earth (separating the waters from the land) and the creation of life. Buckland offers a fourth hypothesis, that the lengths of the days of Creation is not 24 h. He explained that either of the last two would remove issues between geology and the Bible (Buckland 1820: 24). Not all of these explanations were original to him, but this summary proved useful to later authors, who would widely cite him.

While most mainstream geologists of his day lauded Buckland's reconciliation of geology and Scripture, some Biblical literalists were inclined to force geology to bow to the Divine Word. Their works became known as *scriptural geology* or *Mosaic geology,* named for George Bugg's *Scriptural Geology* (1826) and Granville Penn's *Comparative Estimate of the Mineral and Mosaic Geologies* (1822). Penn (1761–1844) was neither a geologist nor a member of the clergy; rather, he was an assistant chief clerk in the War Office and philologist who specialized in early Christian, Classical, and Byzantine literature (O'Connor 2007). He disparaged both the models of Werner and Hutton under the moniker of "mineral geology" and dubbed them "falsehood" to the truth of the literal Bible (Penn 1822: 5-6). His model of Mosaic geology followed directly from Scripture—the six days of creation were six 24-h days, the world was approximately 6000 years old, and all important geological structures derive from two acts of God: the original parting of the waters from the land (accomplished before life was created, thus explaining the lack of fossils in the lower strata), and the Noachian Flood. Penn based much of his argument on the philosophical notions of Isaac Newton, in particular the argument that not only is God the original Prime Cause, but that the laws of nature, as secondary causes, are insufficient to keep the universe running without the continued direct intervention of God.

The extinction of numerous species of animals reflected in the fossil record might be seen as problematic to Biblical literalists who consider the deity to be omnipotent and benevolent. Penn addressed this issue directly, arguing that God ordained which animals were to become extinct: "He who planned and regulated the *creation* of the earth, unquestionably planned and regulated also its *renovation*; and the *extinction of certain animal species*, which existed prior to that last revolution, is proved by their *exuviae,* to have been *a part of His plan in the renovation*" (Penn 1822, 342–3; emphasis original). Penn then argues that the special creation of modern species of animals by God (including those not mentioned in the Bible) is a logical assumption, as God already had to specially create new plants to cover the landmass after the receding of the flood waters.

Without the millions years needed to form rocks through geological processes, Penn's model instead suggested that just as God had made Adam and Eve fully formed—fully grown with their organs formed and bones hardened—the rock strata were similarly formed in their present state, rather than hardening from lava or being deposited one particle at a time. The biological and geological processes seen at work in the world today were not those by which God created the world and its creatures and rocks. Penn attempted to explain rocks that are constructed from older parts (such as conglomerates made of older pebbles and coal made of organic matter) as being the result of the Deluge of Moses. In one of the most curious aspects of his model, the current mountains and continents once formed the ocean floor, which rose after the Flood. The original rocks were somehow able to change places with the previous sea floor and formed a new basin in which to store the immense volume of water required to cover the entire earth in the Deluge.

Penn's work was panned by a number of influential geologists and theologians, but enjoyed some success with the general public. Adam Sedgwick (1785–1873), a clergyman and Professor of Geology at Cambridge, wrote in his *Discourse on the Studies of the University* (1834) that Penn and his colleagues demonstrated a "shameful want of knowledge of the fundamental facts… dishonored the literature of this country… overlooked the aim and end of revelation, tortured the book of life out of its proper meaning, and wantonly contrived to bring about a collision between natural phenomena and the word of God" (qtd. in Hitchcock 1835: 266).

Catastrophism and Neptunism, both of which were deemed relatively friendly to a reconciliation between geology and Scripture, remained popular in Europe through the first few decades of the nineteenth century, but eventually gave way to Uniformitarianism and Plutonism, after the publication of *Principles of Geology*, the seminal work of geologist Charles Lyell (1797–1895). Based on a decade of rock and fossil field work across Europe, Lyell's three-volume work laid out the evidence for a Huttonian model of continuous, gradual geological processes continuing to shape the earth's surface over long periods of time. Lyell explained geological structures though observed processes active in the world today, without the intervention of any supernatural agency. He, like Hutton, did not see evidence of a beginning in the geological world, and was careful to distinguish between geology and *cosmogony*, the scientific speculation about the origins of things. Like Hutton, Lyell was attacked for removing God from this central role, and critics questioned his religious faith. In response, in both the last chapter of volume 3 of *Principles of Geology* (1833) and his 1832–33 public lectures on geology, he affirmed his own belief in a powerful God who created man and all living things according to a great plan, and added that "To assume that the evidence of the beginning or end of so vast a scheme lies within the reach of our philosophical inquiries, or even of our speculations, appears to us inconsistent with a just estimate of the relations which subsist between the finite powers of man and the attributes of an Infinite and Eternal Being" (Lyell 1833: 385). Lyell's pious statements did little to soften the blow his geological studies struck against literalist interpretations of the Bible. Those who subscribed to the arguments of Buckland were less threatened, but many of them were still reluctant to abandon the power of catastrophes and floods and embrace the slow and steady processes of the modern geological world, despite the preponderance of evidence to support Lyell's model. These gentlemen formed the authoritative body of European geology, and were both heavily influential upon, and were heavily cited by, all popularizers of geology, both in England and in America, and especially women writers, who attempted to convince their critics that they had the requisite background to speak about science by citing and quoting these illustrious men of science.

1.3 The Religion of Geology: Silliman, Hitchcock and New England Geology

Attempts to reconcile geology with Scripture were especially popular in America, partly due to the deeply held religious beliefs of many American geologists. This enhanced and prolonged the popularity of Catastrophism and Neptunism in the U.S. throughout the first half of the nineteenth century (Matijasic 1987: 416). The result was a specific type of reconciliation between geology and theology that took the work of Buckland an important step further. Not only was there no contradiction between the two, but geology was seen to provide proof of the events in the Bible, and thus the study of geology, even more so than the contemplation of astronomy, would deepen faith and devotion. This movement became known as the *religion of geology*, a term coined in an 1835 article by one of its main proponents, the Reverend Edward Hitchcock, Professor of Geology at Amherst College. Hitchcock and his friend and former geology instructor, Yale College Professor Benjamin Silliman, greatly influenced American geology during the mid-1800s through their widely-read articles, books, and popular public lectures.

Benjamin Silliman (1779–1864) was a native of Connecticut and grew up in a devout Congregationalist family. He received bachelors and masters degrees from Yale College, and passed the bar in 1802. At the suggestion of Yale President Timothy Dwight he studied chemistry in order to become the university's chemistry professor, and in addition studied geology in Edinburgh in 1805–6, a time of intense debate between adherents of the geological ideas of Werner and Hutton. While he was exposed to all points of view, he favored those of Werner to varying degrees throughout his life, although he eventually espoused a view that modified and synthesized all of these disparate models. For example, in his 1829 *Outline of the Course of Geological Lectures Given in Yale College*, he explained that although it was "the fashion of the day to attribute almost every thing in the earth to igneous agency, I shall probably be thought behind the present state of opinion, while I maintain, that the chemical affinities, through the medium of aqueous solutions of the great chemical agents—as well as of water itself, have also produced important effects in the early arrangements of the planet." His argument was that even though there was irrefutable evidence that igneous processes were important in shaping the earth, scientists should not "exclude any of the great powers, which we find in actual operation; or, of whose ancient activity there appears probable evidence" (Silliman 1829: 3–4). By affirming the power of water, and more especially the actions of water in the past, Silliman kept the door wide open for a scientific discussion of the Mosaic Deluge.

Silliman studied and taught geology at Yale, using the rich geological structures of New England as his laboratory. He widely disseminated scientific knowledge through his own writings and university and public lectures, as well as through his work as the creator and editor of the *American Journal of Science and Arts* (often called *Silliman's Journal*). But religion was ever-central to his geological studies, and was interwoven into his scientific writings and presentations. For example, he opened his introductory lecture with the explanation that "Among the privileges which the Deity has conferred on man, one of the greatest is the capacity and the disposition to acquire knowledge" (Silliman 1828: 5). He then listed various types of human scientific knowledge, beginning with "moral science," which he counted as the "most important branch… which informs us of our condition, as moral and accountable beings, and of our relation to the Creator" (Silliman 1828: 6). Near the end of his lecture, he finally arrived at geology, which he stated "abundantly confirms the truth of the Mosaic account of the creation, and of the succession of its various epochs, and it exhibits, in the arrangement and contrivance of the mineral strata, decisive proofs of the power, wisdom and design of its author" (Silliman 1828*:* 32).

Silliman's geology classes also included numerous references to the Mosaic tradition and how geology could be used to confirm its truth. As in the case of Buckland and the English reconciliation tradition, Silliman openly addressed apparent contradictions between geology and the Biblical chronology and gave his opinions on the various solutions provided by both Biblical and scientific scholars. In the preface of his *Outline of the Course of Geological Lectures Given at Yale College* (1829: 7) Silliman asked the question "Are the discoveries of geology consistent with the history contained in the book of Genesis?" His answer was unequivocal: "Respecting the deluge, there can be but one opinion… geology fully confirms the scripture history of that event" (Silliman 1829). He explained that although the Bible is "not a book of physical science… there are two great events recorded in it, which, although they have a momentous moral bearing, are, *in their nature*, entirely physical; we allude to the creation and arrangement of the planet, and to the deluge which was made to sweep over its surface" (Silliman 1829: 7).

In the same work Silliman (1829: 4) claimed that he was "neither Wernerian nor Huttonian, Neptunian nor Plutonist." He invoked water and fire as needed, and drew upon both catastrophic and slow, gradual processes as needed to explain the particular geological subject at hand. For example, he explained that the "creation of the planet was no doubt instantaneous, as regards the materials, but the arrangement, at least of the crust, appears to have been gradual," but then added a further religious twist by stating that the order of the important steps in this gradual process "corresponds with the *order of the events* narrated in sacred history" (Silliman 1829: 67). Silliman further separated himself from the scientific lineage of Hutton (and later Lyell) in the important respect of openly discussing the creation of the earth, in keeping with his Wernerian leanings (and the perceived natural sympathy between Neptunism and Scripture).

Throughout the body of his *Outline*, Silliman used geological examples to illustrate the benevolent and well-designed plan of the Deity in preparing the planet for its eventual habitation by humans, and affirmed that although the natural world depends on natural laws (which were created by God), God is ever-present in the world to this day. As Buckland before him, Silliman warned against incorrectly attributing the older geological strata to the Noachian flood, and devoted an entire 30-page section to outlining the physical properties of the Deluge, including the depth of the water, its effects (including the extensive diluvia which he saw with his own eyes in the Connecticut Valley), and the source of the extraordinary volume of water required to cover the entire earth. Silliman also used the universality of flood myths around the world as further evidence of the veracity of the Deluge. In his discussion of the geological evidence for the Great Flood, Silliman specifically addressed mastodons, whose fossils were increasingly found in the eastern United State in the early 1800s. He noted that some of the animals present on the ark may have afterwards become extinct through "unknown causes" and that mastodons might be among them. His personal opinion was that although "most of the mastodons perished at the deluge, I have no objection to admitting that some of them, whose skeletons are found, may have perished before, or since that event" and further explained that some may have "foundered in salt licks and marshes… miring, as cattle do at the present day" (Silliman 1829: 93).

Silliman also inserted his views on geology and Scripture into his editions of others' writings. For example, in 1839 Silliman edited the American edition of Robert Bakewell's *Introduction of Geology*. In an Appendix he laid out five solutions to the apparent discrepancies between geology and Scripture, especially the Mosaic chronology. These solutions include the use of periods of indefinite length to explain the six days of creation and a gap of time between the beginning and the first day. However, despite his deeply held religious beliefs, and his desire to use geology to provide evidence for them, Silliman remained rooted in geological theory, and in this Appendix explained that

> our convictions are confirmed by surveying, with Mr. Lyell… that since the creation, as regards geological causes, except their varying if not diminished intensity of action, all things remain as they were; no new code of physical laws has been enacted; while the beginning was with God, the continuation of events is with us, and a distant posterity may not witness their termination. (Silliman 1839: 546)

Silliman was also critical of Penn's Mosaic geology, although much more gentle in his criticism than Sedgwick and others. In his *Outline of the Course of Geological Lectures*, Silliman (1829: 77) noted that although his fellow Christian had "served the cause of truth," his work "has, in our opinion, left the question between the critics and the geologists embarrassed with all its difficulties." In a 1834 letter from English paleontologist Gideon Algernon Mantell (1790–1852) to his friend, Charles Lyell, Mantell marveled at the size of the enthusiastic audiences at Silliman's public lectures, and expressed wonder at Silliman's ability to uphold the geology of Lyell while simultaneously reassuring his god-fearing audience that the new geology did not contradict their Holy Book (Wennerbom 1999). Ironically, Silliman later edited the American edition of Mantell's *The Wonders of Geology* (1839) and included an