

A Study of the Christian public's engagement with the new Geology of the 19th century and its implications for the succeeding centuries

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Abstract. While Christian communities had no problem engaging positively with the sciences of astronomy, physics and chemistry, they had difficulty engaging with the emerging geology and biology of the 19th century. The ancient earth and evolutionary models of geology and biology respectively were seen as a direct attack on the biblical Genesis model of a young earth and a creation that took place over the period of a week. Some Christian apologists used Baconianism and the Scottish Common Sense philosophy to suggest that geology was not a real science. Geology was characterised as consisting of wild speculation, hypotheses and theories and lacking in solid factual evidence. In both Britain and North America Christian respondents to the new geology were classified as *harmonizing geologists* or *scriptural geologists*. This paper considers the nature of these respondents, their philosophical positions, and how these positions took form in the succeeding centuries in terms of different cognitive geological styles. The implications for the science education and science in society context will be discussed.

Introduction

The current public portrayal of Christian thinking alongside Scientific thinking across a variety of media might suggest that there exists a fundamental disjunction between the two, a disjunction often vigorously expressed when it comes to sensitive topics like the age of the earth or the origin of life. However, in the past the relationship might be better described as symbiotic rather than disjunctive. In fact, Peter Harrison (1998, p. 8) argues that the Protestant approach to the interpretation of its sacred texts was a “major catalyst in the emergence of (modern) science”. While there were multiple factors responsible for the emergence of science in the 16th and 17th centuries, “by far the most significant was the literalist mentality initiated by the Protestant reformers, and sponsored by their successors”. Just how this came about is worth exploring briefly as it forms a foundation for what transpired in the 19th century and succeeding centuries.

From the 2nd to the 4th century Christian documents which were considered by Christian communities to be ‘authoritative’ for belief and practice were brought together to form what was to become known as the *New Testament*. This, along with the *Old Testament* borrowed from the Jewish faith, became known as the *Holy Scripture*. The early church fathers such as Origen (c.185-c.254) understood that the scripture had three senses (Origen, 1973): the *literal* which was the obvious or historical sense, the *moral* which gave instruction on how to live, and the *allegorical* which was to be given precedence as it pertained to timeless theological truths. While Noah’s ark could be thought of in a literal sense, the ark and the flood had deeper theological significance (Lewis, 1978). To the church fathers the ark

was a symbol of the church, with the occupants inside destined to be saved, and those outside destined to be lost. The flood waters represented on the one hand those passions which bring death and destruction, but on the other hand, the cleansing waters of baptism. The three levels of the ark were also given multiple meanings: earth, sky, and abyss; the three stages in the development of the church; faith, hope, and love; and Noah's three sons. The breadth of the ark (fifty cubits) symbolised the fifty days of Pentecost. The height (thirty cubits) symbolised the thirty years of Jesus life. The length (three hundred cubits divided into six lots of fifty cubits) represented the six ages of the earth.

Up to medieval times the principles upon which nature was studied closely paralleled the principles upon which scripture was studied. Nature was studied, not for its own sake, but for divine reasons. In a work entitled, *Physiologus*, of unknown official authorship but thought to most likely be authored by one of Origen's students (Harrison, 1998, p. 23), the pelican, because of its propensity to strike itself and shed its own blood on its young to revive them from trauma, became an enduring symbol of Christ's atonement. Even when elements of nature are mentioned in *scripture*, the emphasis was on their symbolic meaning. In the Genesis account of creation, light and darkness represented *just* and *unjust* souls; lights in the firmament were *spiritual gifts*; herbs and fruit-bearing trees were *good works*; and wild beasts represented the *passions* which needed to be brought under the dominion of reason (Augustine, 1991, pp. 291, 295f).

Harrison (1998, pp. 45-46) reminds us that these moral and allegorical readings of scripture and nature, "while they may seem to the modern mind somewhat arbitrary and haphazard, were something of a science, requiring of the exegete remarkable skill and ability". The symbolism and associated meaning became endemic to the way Christian faith was practised to the extent that the reading and interpretation of scripture and nature became the province of the scholars of the church rather than the laity of the church. This tradition was challenged during the Protestant reformation of the 16th century. For 1500 years ecclesiastical tradition dictated how scripture and nature should be read and understood. The Reformation proposed at least three changes which were to have an impact on the emergence of modern science:

1. Scripture was to take primacy over tradition in Christian faith and practice.
2. If scripture was to take primacy, it should be available for everyone to read and interpret according to their own conscience.
3. If scripture was to be made available for everyone to read and interpret, then the literal sense had to be the primary sense as this was the sense that didn't need the advanced skills of the scholar for interpretation. This also meant that scripture needed to be translated into the vernacular.

Harrison (1998, pp. 117, 120) asserts that the "Protestant Reformation, by promoting the culture of the literal world, effected a dramatic contraction of the sphere of the sacred, forcibly stripping objects, natural and artificial, of the roles they had once played as bearers of meaning.....It was left to an emerging natural science to reinvest the created order with intelligibility,...that systematic, materialistic understanding of the world embodied in the privileged discourses of natural science".

In line with this movement away from the allegorical sense of interpretation was Francis Bacon's (1561-1626) development of a method of philosophical reasoning about

nature based on what he called “simple experience” (Bacon, 1818, p. 69). Observation, based on the senses of sight, touch, smell and sound could be used to accumulate data about the world which could eventually lead to generalisations from the data. Bacon believed in the design of experiments based on data already accumulated so that new data could be furnished for the natural philosopher. His philosophy of nature based on simple observation and experiment resonated with the “common sense” ideas of the 18th century Scottish philosopher Thomas Reid (1710-1796). Bacon’s philosophy of science, as it became known in the 19th century, combined with Reid’s ‘common sense’ philosophy, was readily adopted in North America because, as Holifield (2004, p. 2) argues, it was seen to “protect and preserve theological truth” as it eschewed speculation, hypotheses and theories, factors believed to be central to the emerging geology which was challenging Christian faith.

Geology-an emerging science of the 19th century

It is generally acknowledged that natural philosophy took on the format of modern science during the nineteenth century. Andrew Cunningham (1988, p. 385) claims that the “invention of science” was “an historical event of the period c1780-c1850”. During the same period the previously all-encompassing field of natural history started to transform into separate scientific disciplines such as geology and biology. According to Rudwick (2005), the introduction in 1778 and quick acceptance in the following years of the term *geology* for the new science is generally attributed to Jean-André Deluc (or de Luc, 1727-1817) and Horace-Bénédict de Saussure (1740-99). Geology started to differentiate itself from earlier notions of geognosy, which dealt with observations on the structure, sequence, and mineralogy of rock formations. While geognosy was “rigorously observational and empirical, usually detailed and local, and primarily descriptive rather than causal in its aims”, geology, which also used much observational evidence, had implicitly “high-level causal explanation” as its goal (Rudwick, 1997, p. 6). The deeper roots of geology go back several centuries, but modern geology as we now know it went through an extraordinary strong formative period around the turn of the nineteenth century (Laudan, 1987). Indeed, the roots of several important geological ideas go back as far as the seventeenth century (e.g. Robert Hooke on the occurrence of fossils and their potential for a chronology; Nicolaus Steno and the stratigraphical principle of rock strata) (Oldroyd, 1996), but those ideas only came sharper into focus towards the nineteenth century. Geology was becoming increasingly distinct from the earlier fashionable cosmology or cosmogony (or cosmogeny) of the seventeenth and eighteenth centuries.

From the 1780s onwards, geology became one of the emerging sciences where philosophical discussions of a desired scientific methodology shaped its development (McGrew et al., 2009). Early geologists realised that for the new science to become respectable it had to separate itself from the premature and indiscrete use of unverified hypotheses of the past. For example, in 1807 on the occasion of a book review for the *Classe des Sciences Physiques et Mathématiques* of the French *Institut National*, the French naturalists Georges Cuvier, René Just Haüy and Claude-Hugues Le Lièvre (1807), provided some reflections on the state of geological matters. They stated that *géologie* has too many theories, is based on too few facts, and that therefore, among the younger generation of naturalists, the mention of the name geology tends to provoke laughter. Cuvier, Haüy and Le Lièvre asserted that for geology, as a branch of natural philosophy, to become a respected science it needed to base itself on facts, observations and induction. They outlined several

points that were deemed essential for making geology a real science with its own doctrine (1807, pp.422-424).

In the same year, 1807, the Geological Society of London was founded and it unequivocally stated its strong emphasis on observations and the collection of facts. Within the first two years of its existence its members realised that the image of geology within the scientific community needed to be improved by getting rid of the perception of a speculative and *a priori* type of science (Laudan, 1977). For that, its intended legitimating methodology needed to be put on a sound empirical footing. The Society embarked on a program of cooperative data gathering and adopted old-fashioned Baconian induction as their anti-theoretical, well-established method of scientific inquiry. In 1809 the Society agreed, based on their chosen Baconian methodology, to prepare as a program of action a geological map of the entire country. This action plan provided a stimulus and guidance for geologists to collect field data.

Rudwick (2009, p. 103) notes a radical transformation in the Earth sciences during the period, 1800-1825, by their “becoming deeply historical in their outlook and practice.” Geologists realised that features such as mountains, volcanoes, rocks, and fossils have histories built into them that can be analysed. Geologists started to ‘think historically.’ The deciphering of the earth’s history was however complicated by the fact that it was not directly observable and only fragmentarily preserved (Rudwick, 2004). Towards the turn of the century therefore, there arose a new emphasis on fieldwork and data collection rather than the construction of the speculative theories of old such as Thomas Burnet’s *The Theory of the Earth* (1684). As a result of this new prominence of empirical fieldwork, a stratigraphic column based on the accumulated data, and independent of any major publications on evolutionary thought, became a reality early on in the nineteenth century.

However, Laudan (1977) argues that the outdated, conservative form of Baconian induction quickly stifled any theoretical innovation and development needed for scientific progress. In the 1820s a younger generation of members of the society started to argue for their various speculative theories and to embrace and put into practice a more liberal methodology. Laudan (1977) feels that only from then onwards did geology in England begin to flourish and to influence the wider development of science. It had been common during the nineteenth century to see the investigations and speculative theories of the seventeenth and eighteenth centuries as a hindrance to the progress of geology. This is often ascribed to Charles Lyell’s (1830) craftily rewritten tendentious version of geological history for his introduction to his *Principles of Geology* (see Rupke, 1994). This myth persisted in the geological literature until the 1960s. Roy Porter (1977) was one of the first to argue that those activities and ideas of the preceding centuries had instead actually provided a valuable basis for the rapid development of geology during the 19th century.

Geology and Religion in Britain

The creation event recorded in Genesis 1 and 2 and the global flood narrative recorded in Genesis 6-8 were now read by Christian communities not so much as moral or allegorical lessons in virtue but as literal historical events of geological significance. Two groups of people with an interest in geology and religion during the first half of the nineteenth century can be traced here. The first group may be called the *harmonizing geologists*: generally practising geologists of academic standing that had an earnest desire to reconcile Genesis with the emerging geology. The second group may be classified as the *scriptural geologists*: individuals who had strong Christian apologetic motives and generally without much (or any) practical experience in geology. These groups are particularly relevant because they influenced the development of their counterparts in North America.

Harmonizing geologists

Amongst the harmonizers we find William Buckland (1784-1856), Adam Sedgwick (1785-1830) and William D. Conybeare (1787-1857), all geology professors connected to the Anglican institutions of higher learning. In addition there is the Congregationalist John Pye Smith (1774-1851), and most of all Hugh Miller (1802-1856), best known for works such as, *Footprints of the Creator* (1849), and *The Testimony of the Rocks* (1857). One of his famous quotes clearly characterises his disdain for the group of scriptural geologists (Miller, 1857, p.141): “The writings of Moses do not fix the antiquity of the globe.” The most widely sold publication from among the harmonizers however was Buckland’s *Bridgewater Treatise: Geology and Mineralogy considered with Reference to Natural Theology* (1836).

Most of the geologists belonging to this group reconciled a genuine interest in geology based on geological fieldwork with Scripture. They would either use the gap theory or the day-age approach to find harmony. The gap theory proposed that millions of years could have been present between Genesis 1:1 and Genesis 1:2 and the day-age approach supposed that each day of the creation account could represent thousands or millions of years. These were tools the *harmonizers* used to reconcile the Genesis account of creation, thought to have occurred about 6,000 years ago according to Ussher’s chronology, with the long ages of the emerging scientific geology. Even in the face of new conflicting geological data they would not give up their desire to seek harmony and to staunchly keep their faith. They were often the target of the scriptural geologists who saw the harmonizers as not being true to the Scriptures.

Scriptural geologists

Mortenson (2004) defines scriptural geologists as those who claimed that all geology was within the confines of Six Days and a Universal Flood. For him ‘scriptural’ means a literal hermeneutic (Roberts, 2008, p.101). The scriptural geologist, sometimes referred to as an anti-geologist (Miller, 1857), strongly believed that only a literal-narrative view of the Bible could be a correct interpretation. Lynch (2002, p. xii) is convinced that “scriptural geologists represented a backlash against geological developments in the early 1800s,” and he characterises the scriptural geologists as follows: “few of these critics had any first-hand experience in field geology, most showed little presence in the emerging professional societies, had comparatively few scientific publications, and would not have considered themselves to be ‘geologists’.” The fact that they did not ‘do’ any geology seemed to have annoyed the expert geologists mostly. In 1827 Charles Lyell, for example, expressed his displeasure with the writings of the scriptural geologists as follows:

We cannot sufficiently depreciate the interference of a certain class of writers on this question . . . While they denounce as heterodox the current opinions of geologists, with respect to the high antiquity of the earth and of a certain class of organic beings, they do no scruple to promulgate theories concerning the creation and the deluge, derived from their own expositions of the sacred text, in which they endeavour to point out the accordance of the Mosaic history with phenomena which they have never studied, and to judge of which every page of their writings proves their consummate incompetence (in Lynch, 2002, p. xiv).

Stiling (1999) sees the appearance of scriptural geology in Great Britain more as a response to an attempted new biblical understanding of the growing accumulation of new geological information than as an initiative by an emerging group of reactionaries. Scriptural or Mosaic geology emphasised the “cognitive validity of the biblical narrative,” while they,

the scriptural geologists, contrasted the “fanciful” theories of the geologists with their own “commonsense” conclusions. Stiling (1999, p. 177) explains the motives of the nineteenth century scriptural geologists as a wish to “protect and preserve the Bible from the perceived encroachments of a threatening science,” and to come against “any hermeneutical compromises that ill-advised interpreters of Genesis might inappropriately grant to promoters of geology.” The last section was clearly directed at the harmonizing geologists of their times.

Warren Johns (2008, p. 45) added an extra dimension to the historiography of the British scriptural geologists by astutely revealing evidence of belief in a diminishing geological deluge amongst them. Johns gives striking examples of how British scriptural geologists “shifted the pre-Flood/Flood boundary higher and higher in the geological column.” He provides the case of George Fairholme (1789-1846) who shifted from the view that the Flood formed the entire fossiliferous geological column to the view that some of the deposits were actually antediluvian and limited the Flood to the upper portion of the geological strata. Although the shift to a diminishing geological deluge had started as early as the 1830s, Johns argues that the recognition of the effects of the Ice Age by the 1860s had removed the need of the Flood as a geological agent amongst the harmonizing *and* the scriptural geologists in Britain. However, this was not to be the case in North America for the scriptural geologists.

Geology and Religion in North America

North America had, just like Great Britain, eminent harmonizers that were committed to establishing harmony between Genesis and geology. The most well-known representatives of the American harmonizing geologists were Benjamin Silliman (1779-1864), Edward Hitchcock (1793-1864), the Swiss immigrant Arnold Guyot (1807-1884), James Dwight Dana (1813-1895), the Canadian Sir John William Dawson (1820-1899), and George Frederick Wright (1838-1921). Silliman and Hitchcock both stand out when considering their contributions towards reconciling Genesis and geology in the first half of the nineteenth century. Both were equally dedicated to the domains of professional geology and theology. They remained so in the face of newly emerging geological findings. It is not difficult to see similarities between them and their British harmonizing counterparts.

The appointment of Benjamin Silliman to the Professorship of chemistry and natural science at Yale University was a very significant landmark in the history of American geology. As a Wernerian he was to teach the subject to many Americans and give popular lectures throughout the eastern states (Ospovat, 1960, p. 100). Silliman was one of the first harmonizing geologists who “gave careful and sustained attention to the reconciliation of geology and religion” (Stiling, 1991, p. 45). Stiling (1999, p. 179) describes Silliman as “no theological liberal” who “reinterpreted the Bible by adopting a “day-age” harmonizing scheme for Genesis and geology which was at the time popular in Europe.” Silliman remained confused, however, about precisely what geological results to attribute to the Genesis Flood. This rising enthusiasm concerning the geological evidence for the Flood during the 1820s would reach its peak in the middle of the 1830s. Edward Hitchcock became the great catalyst for this process.

Edward Hitchcock (1793-1864) was Benjamin Silliman’s student, colleague and friend. Hitchcock was undoubtedly an important figure in nineteenth century American science; he contributed significantly to the fields of geology, palaeontology and palaeoichnology (the study of fossil bird tracks which were later interpreted as dinosaur tracks). He developed the notion of the “Christian Geologist” who would be committed to reconciling geological facts with the Mosaic narrative (Segal, 2005, p. 1). He supported

Chalmers's gap theory to reconcile Genesis and geology. In the period between the 1820s and 1850s Hitchcock would experience a dramatic change in his perspective on the relationship between the geological phenomena and the biblical account of Noah's Flood. During the 1820s he could confidently state that "the geological evidence for the Genesis Flood appeared as strong and convincing as the historical evidence" (Stiling, 1991, pp. 51-52). However, by 1851 Hitchcock would express the general sentiments of the American geologists in declaring of the Flood that "those best qualified to judge now doubt whether it be possible to identify one mark of that event in nature" (Hitchcock, 1851; Stiling, 1991, pp. 51-52).

Early nineteenth century American geology, just like its European counterpart, used abundant anti-theory rhetoric but was never totally free of implicit theoretical thinking. It showed that theory could not be disconnected from observation and data collection during fieldwork. Newell (1993, p. 176) explains that, "Identification of rock strata, construction of nomenclatures, correlation of distant formations, and depiction of stratigraphic units in maps and sections all required high levels of theory-based activity and elicited explicit discussions of the theoretical foundations of practice." Geology in America, therefore, included both "gathering and correlating stratigraphical information for broad areas of the continent and formulating theories to account for the large-scale disturbances clearly undergone by the strata" (Newell, 1993, p. 177). The emphasis on fieldwork in this process contrasts sharply with the opinion of nineteenth century churchmen who felt justified in discussing and critiquing the findings of professional geologists. They appealed to their perceived common sense nature of geology when it had long stopped being a common sense science. Criticism of the emerging place of theory in the natural sciences had initially come from the scientists themselves, but it was the American Scriptural Geologists who were to become the outspoken critics of hypotheses, theories and speculation.

The Troika of American Scriptural Geologists

There were three Scriptural Geologists in North America during the 1817-1857 period; Eleazar Lord (1788-1871), David Nevins Lord (1792-1880), and Martyn Paine (1794-1877). All three happened to reside in New York City. Stiling (1999, p. 181) astutely observes that "all [Scriptural geologists] wrote in objection to the reconciling trend [of the harmonizer geologists], and all three [Eleazar Lord, David Lord, and Martyn Paine] wrote before the advent of Darwinism." Scriptural geology was therefore *not* about combating Darwinian evolution. According to Stiling (1999) it was especially Edward Hitchcock's publication of his classic science-reconciliation text, *Religion of Geology and Its Connected Sciences* (1851), that had triggered the appearance of scriptural geology in the United States. Hitchcock had stated that an insistence to accept miracles as a possible factor in earth history was to preclude scientific investigation. Eleazar Lord strongly disagreed and felt that "nature could testify even to the supernatural." Lord "assigned the surface drift phenomena, the coal beds, and all of the sedimentary strata to the period associated with the Flood" (Stiling, 1999, p. 181).

During the late-1830s and early-1840s Eleazar Lord anonymously published material against the "hypothesis of geologists respecting the creation," which he understood to be the conceptions of an old earth and a limited or insignificant Flood (Lord, 1837, p. 526). The published work was basically a critique of William Buckland's *Bridgewater Treatise*, in which Buckland had attempted to harmonize geology with scripture and conceded a limited Flood. Lord rejected the attempt to harmonize geology with scripture and admonished a strict adherence to the Mosaic narrative (Lord, 1837, pp. 526-538). He strongly argued on philological grounds against the gap theory on the basis of the Fourth Commandment.

Sabbath day observance “could not have been prescribed, had the heavens and earth been created myriads of ages before the creation of man” (Tison, 2008, p. 235). Lord felt strongly that the age of the earth should be interpreted in the light of Scripture and *not* on the basis of extra-biblical reasoning. The big problem with theoretical geology was, according to Lord, the use of extra-biblical epistemology and the naturalistic methodology of science, each of which avoided the necessity of miracles.

David Lord, a brother to Eleazar, became known for his establishing and editing the quarterly *Theological and Literary Journal* in 1848 and his publication of a book entitled, *Geognosy, or the Facts and Principles of Geology against Theories*, in 1855, with the second edition in 1857. The *Journal* was used to question the geologists’ underlying assumptions, to highlight the miraculous possibilities of a sovereign God, and to place divine revelation, as it appeared in the sacred *Holy Scripture*, in a position of *primacy* over natural science.

“Geognosy” was obviously chosen as the main title for his book to emphasise the importance of describing the composition and arrangement of the materials of the earth without recourse to speculative theories. It was a term used by Werner in connection with a factually based rock classification.

Dr. Martyn Paine (1794-1877) was a Harvard educated medical doctor who equally strongly opposed modern geology. Paine was supportive of the views of the two Lord brothers. His first thoughts of a scriptural-geological nature can be found embedded in *A Discourse on the Soul and Instinct, Physiologically distinguished from Materialism* (1849), where he emphasises the importance of the 24-hour days in the Creation week and strongly connects his argument with the Fourth Commandment.

Both the Lords and Martyn Paine used the term “theoretical geology” in a pejorative fashion to criticise the assumptions that sediments of the fossiliferous strata were deposited under relatively uniform and tranquil conditions. The suggestions of an ancient earth and limited effects and extent of the Flood were totally undesirable to them. Paine abhorred the theological implications of modern geology and was convinced that this was opening the door for widespread infidelity. Instead, Paine (1849) strongly promoted a literal understanding of the creation and Flood narratives, and a young earth. He unambiguously attributed the stratified fossil-bearing rocks to a world-wide Flood. This view was based on a combination of the evidence of the Old Testament account of the Flood in Genesis, the New Testament references to the Flood by Jesus and the apostles, and the coal formations.

North American geology emerged in the beginning decades of the nineteenth century as an offshoot from European, and especially British, geological thought. Wernerian thinking guided the first mapping projects across the continent but gradually an authentic American stratigraphy was recognised and incorporated in the global geological column. American harmonizing geologists went through the experience of recognising a diminishing geological *deluge* just like their British counterparts. However, the small group of American scriptural geologists, in contrast to their British counterparts, did not concede that the earth was very old, that a geological *deluge* was of diminishing importance, and that the Genesis Flood could have been localised. Strongly influenced by Christian Baconianism they defended their interpretation of a Mosaic geological deluge and criticised reconciling endeavours by others. It was in the 19th century when a sacred text thousands of years old had to engage with an emerging geological science and an emerging secularism. How one might classify the ingredients of this engagement is the topic of the next section of this paper. Such a classification might be of assistance in understanding how a 19th century engagement might inform current engagements between a Christian worldview and the earth sciences.

Cognitive Geological Styles and approaches to a Sacred Text

Martin Rudwick (1982) has chosen to classify the different approaches to earth science or geology in the 19th century in terms of the ‘different ways of thinking’ or ‘cognition’ evident amongst the practitioners of the emerging discipline. The so-called ‘cognitive styles’ are the *abstract*, the *concrete*, the *agnostic*, and the *binary* style. The relationships between these styles, shown in Figure 1, help one to appreciate the distinguishing characteristics of the styles as well as some of the similarities. In practice a geologist would not necessarily exhibit only one style but may exhibit two or more styles. The kind of 19th century geologist whose style was predominantly, *abstract*, *concrete*, *agnostic*, or *binary* was the *theorising* geologist, the *classification* geologist, the *exploration* geologist, or the *scriptural* geologist respectively.

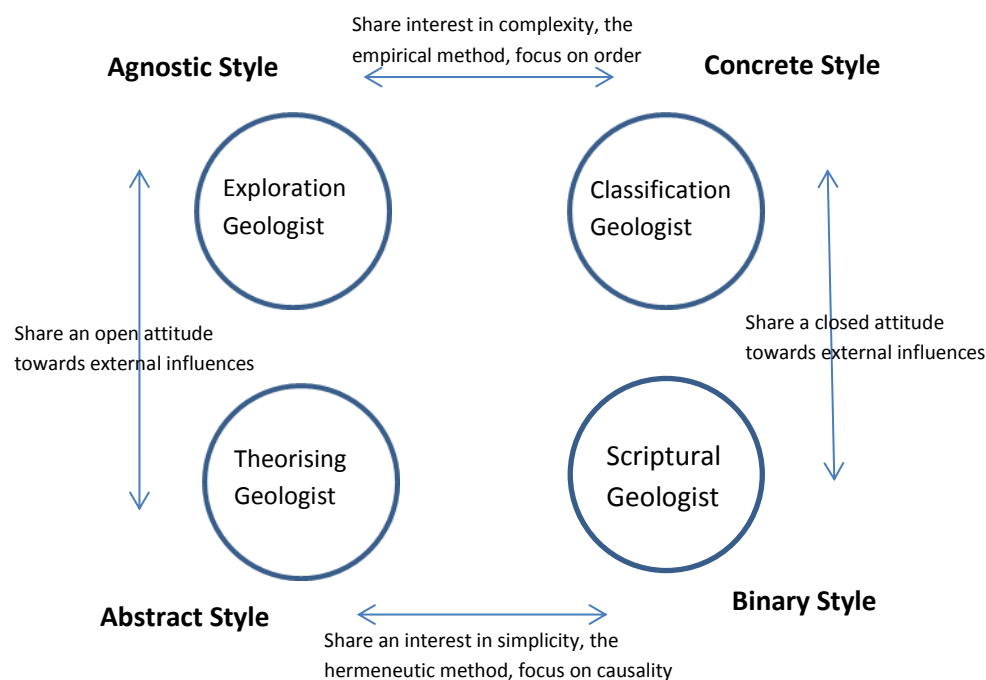


Figure 1. Cognitive Styles in Geology in the 19th century based on Rudwick (1982), but with some adaptations.

The scriptural geologist was a strong representative of the binary style of thinking in that earth history was seen as divided into two stages; that before the biblical flood, and that after the biblical flood. The theorising geologist was interested in establishing a global picture of earth history and was not so much interested in local geological formations and rock layers. Both geologists were interested in interpretation rather than empiricism and in establishing causal mechanisms for earth history. However, the scriptural geologist focused on the data from an ancient text whereas the theorising geologist focused on the data resident in the earth.

The classification geologist was devoted to determining the properties that distinguished one rock layer from another and determining the order in which the various rock layers were deposited. It was in this sense that the style of thinking was concrete as opposed to abstract. Practical experience gained from long working hours in the field was required. These were the hallmarks of the emerging discipline of geology in the 19th century which began to create a boundary rather resistant to ideas from outside the discipline. The

discipline for the scriptural geologist was the sacred text which had also become resistant to external change.

The horizon for the exploration geologist was local rather than global and, like the classification geologist, depended on hours of practical experience in the field. The style of thinking was agnostic in the sense that there was an ambivalence to a theory of earth history. The boundaries defining the thinking style of the exploration and theorising geologist were not as resistant to external influences as was the case for the scriptural and classification geologist.

According to scriptural geologists, practising geologists were not engaged in the ‘discipline of science’ like practising physicists and chemists. Geology seemed to be populated with wild speculation, hypotheses and theories, and lacked the precision of physics and chemistry. It should, of course, be remembered that such accusations had also been made by practising physicists and chemists of their own disciplines in their historical development. Both Priestley and Lavoisier were committed to a discipline of ‘facts only’, but the irony was that Priestley and Lavoisier depended on the ideas of ‘phlogiston’ and ‘caloric’ respectively to explain their observations (de Berg, 2014). But the scriptural geologists did have a point in suggesting that geology was different in some sense to physics and chemistry. As previously discussed, geologists responded to such accusations coming both from within the geology movement and from without by increasing its observational and related fieldwork status. The ‘uniformitarian’ proposition put forward by Charles Lyell was designed to add precision to the discipline. Apart from these efforts, however, there remained distinct differences between the traditional sciences and geology, differences particularly noted by a Christian movement being challenged by the findings of the new geology. But the challenge was not only experienced by some in the Christian movement but also by some in the sciences. Dolphin and Dodick (2014, p. 557) comment that this trend has continued in recent times where “some scientists do not accept the methodological diversity of the sciences and specifically disparage the earth sciences as being less scientific than the physical sciences”.

As far as we can tell, the differences were not well articulated until the 20th century. It was then that the earth sciences along with evolutionary biology were classified as ‘historical sciences’ as distinct from ‘experimental sciences’ because they “developed specific methodologies to cope with problems that could rarely be tested under controlled laboratory conditions” (Dolphin and Dodick, 2014, p. 557). This does not mean that controlled experiments are not part of some branches of modern geology such as geochemistry, but the overall philosophical flavour or style of thinking seems to fit well into the ‘historical science’ category. A table of comparison, due to Dolphin and Dodick (2014, p. 558), is shown below as Table 1.

Table 1. Methodological contrasts between the experimental and historical sciences

Dimension	Experimental	Historical
Research goal	General laws and behaviours	Explanations for ultimate and contingent causes
Evidence gathered by	Controlled manipulation of nature	Observing/analyzing preexisting entities and phenomena
Hypotheses are tested for	Predictive accuracy	Explanatory accuracy
Objects of study	Uniform and interchangeable entities	Complex and unique entities

It can be seen from Table 1 that ‘hypotheses’ are important in both the experimental and historical sciences for the growth of scientific knowledge. However, while a single working hypothesis might be applicable to an experimental science like physics, multiple working hypotheses (MWH) have been of more value in historical sciences like geology.

Dolphin and Dodick (2014, p. 564) point out that because earth science “focuses on complex natural systems, which are often the result of several irreducible causes, ..the application of MWH makes it more likely that a scientist will see the interaction of the several causes”. So, while some scientists such as Priestley, Lavoisier, and some geologists at the beginning of the 19th century eschewed the role of hypotheses in knowledge generation, it is the very existence of hypotheses across the spectrum of the sciences that has led to the explosion of scientific knowledge. But it has been the inherent differences between the experimental and historical sciences that has led some Christians and some scientists to question the legitimacy of the historical sciences.

The strong Christian traditions in both the British and North American sciences leading up to the 19th century and the growing secularism within the 19th century led to different ways geologists confronted the sacred text of the Old and New Testaments in the 19th century. There were at least three styles of thinking or orientations toward the sacred text as geological knowledge expanded at this time. These are summarised in Figure 2.

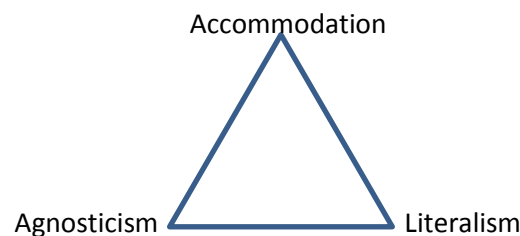


Figure 2. Three orientations to the sacred text in the 19th century.

The harmonizing geologists used the principle of ‘accommodation’ when confronting geological ideas which seemed contrary to scripture. So the ‘days’ of Genesis 1 were interpreted as ‘long ages’ and the ‘global flood’ of Genesis 6-8 interpreted as a ‘local flood’. The scriptural geologists took a literalistic approach to the ‘days’ of Genesis 1 claiming that the days are in fact the days of the 7-day week. Both harmonizing and scriptural geologists took the sacred text seriously. The difference seemed to lie in the fact that the scriptural geologist believed in the primacy of scripture in all things, a result of the Protestant Reformation’s belief in *Sola Scriptura*. The harmonizing geologist was more disposed to giving science and scripture equal voice in matters relating to nature. Agnosticism toward the sacred text gave primacy to science in matters of nature and was of the opinion that the traditions of the sacred text, which once may have served the nation, ceased to have relevance in the modern age. This growing secularism became very evident during the 19th century.

While it is true that the influence of the scriptural geologists in North America began to wane towards the end of the 19th century with the death of the Lord brothers and Martyn Paine, the cause was reawakened by George McCready Price in the early 20th century with his *Flood Geology* (Numbers, 2006). From the 1960s the *Creation Science Foundation* and related organisations vigorously promoted the biblical flood model and have become the modern equivalent of the 19th century scriptural geology movement. All such movements give primacy to scripture over science and in particular, geology and evolutionary biology, although the movements stipulate they are not anti-science. The significant growth of such movements in the 20th century took place, unusually, amidst a biblical scholarship that could only be described as a *progressive* one, although snippets of it have surfaced at least since the time of Augustine. So, in the 20th and 21st century there are at least four approaches to the sacred text as shown in Figure 3.

The progressive approach understands the sacred text as *creating a world for*

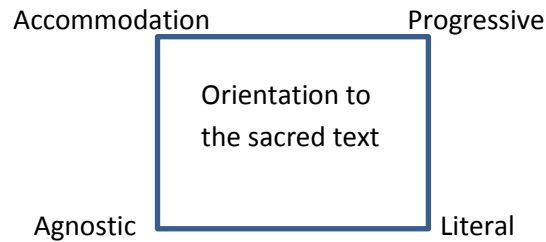


Figure 3. Orientation to the sacred text in the context of 20th and 21st century geology.

theological purposes rather than *describing a world for naturalistic purposes*, seen as the province of science (Harrison, 1998, p. x). The American theologian, Fritz Guy (1999, p. 148) doesn't try to harmonize the Genesis creation record with the findings of modern geology as did the harmonizing geologists, but insists that it should be read as it reads with a focus on its theological content.

Scripture's predominantly theological concern is evident in the phenomena of scripture itself. A clear example is the description of creation in Genesis 1:1-2:3, which has the literary style and structure of a poem or hymn, and its subject is the creative power and ontological ultimacy of God in contrast to all other gods. A careful, straightforward reading of the text discloses the primary focus of attention to be not the details of the creative process but the involvement of the Creator. ..The purpose of this passage is to proclaim the preeminence of God and to establish the significance of the sabbath.

The Old Testament scholar, Laurence Turner (2004, p. 22), draws attention to the cosmological context in which Genesis 1 was written and suggests that it was the theological rather than the cosmological message that was challenging the reader.

It (Genesis) challenges the *theological*, but not the *cosmological* views of Israel's neighbours. An ancient person who read Genesis 1 would not have been surprised by its cosmology, but would have been scandalised by its theology. This gives us an important insight into the purpose of the account....(Genesis) uses commonly held ancient cosmological views as a vehicle to convey theological truths to its original readers.

These ideas have important implications for how earth science education might be conducted not only in a Christian education context but in the broader science education context. Some of the issues will now be earmarked in our conclusion.

Conclusion

Dolphin and Dodick (2014) draw attention to the fact that earth and space science education have been and still are the poor cousins of the more traditional biology, chemistry, and physics education contexts. This is in spite of the central role that such an education could play in helping our civilization deal with issues in climate change, the impact of earthquakes and volcanoes on our living spaces, and also in responding sensitively to Christian organizations that feel challenged by discoveries such as 'deep time'.

When the 'nature of science' standards were first published they tended to reflect largely the 'experimental' sciences as discussed in this paper. What is becoming clear is that the standards need to be broadened to include the 'historical' sciences. Adding breadth to what might be considered a 'science', while meeting with some opposition from within the

traditional disciplines of science and from without, might just enhance the opportunity to develop a more tolerant attitude amongst scientists themselves and also those students we educate in the sciences. Christian organisations brought up on a strict Baconian view of science might also be encouraged to view the word ‘hypothesis’ or ‘theory’ as helpful ingredients of both the experimental and historical sciences. While the impact of societal issues such as economics and politics on the growth and practice of scientific knowledge have been deemed important in a science education, we agree with Michael Reiss (2014, p. 1644) that science educators might also consider “the importance of religion as one of many factors that influence the way science is practised and scientific knowledge produced”.

This does not mean, of course, that science educators should teach religion in their science classrooms. It simply means that just as a teacher might be aware of the impact that political decisions might have on the practice of science, there is no reason not to expect a teacher to have some idea of the impact religious belief might have on the acceptance or rejection of scientific knowledge. Reiss (2014, p. 1655), for example, views creationism not as a misconception but as a non-scientific worldview and makes the following helpful comment:

..a student is likely to have far more of personal significance invested in a religious worldview than a scientific misconception. It is clear that the personal implications of abandoning a belief in a literal reading of the chronology of *Genesis*, including the 6 days of creation as 6 periods each of 24 hours, are far greater than of discarding a presumption that plants gain most of their mass from the soil...Many scientific misconceptions are relatively discrete-one can discard one without affecting much else of one's scientific understanding. Abandoning creationism entails accepting the notion of Deep Time, the relatedness of all life and the realisation that there is no *scala naturae*.

Even given this most appropriate caution regarding worldviews, we think there is much to be gained in introducing science teachers to the different ways the sacred text of the Old Testament has been read from medieval times through to the Protestant Reformation and on to the progress that has been made in recent biblical scholarly readings. While such an exercise might be most appropriately led by specialist teachers of religion, we envisage that this could be suitable as part of a professional development involving scientists and biblical scholars with science teachers and science educators. Even in this exercise there may be a clash of worldviews, but hopefully a tolerant discussion of such worldviews leading to sympathetic understanding.

Controversies between ideas often occur because these ideas are inherently progressive and we believe this has been the case between Christian ideas and geological ideas. For scientists and science educators who espouse the Christian faith, we are of the opinion that a ‘progressive’ reading of the sacred text will prove the most helpful when dealing with apparent discrepancies between geological science and Christian belief. For those who do not espouse the Christian faith, we think the issues discussed in this paper might help in understanding the points of view expressed by students who come from a Christian background. In any case, it is the free expression of ideas in a tolerant atmosphere and the search for evidence combined with deep historical insights which pave the way for extraordinary learning.

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