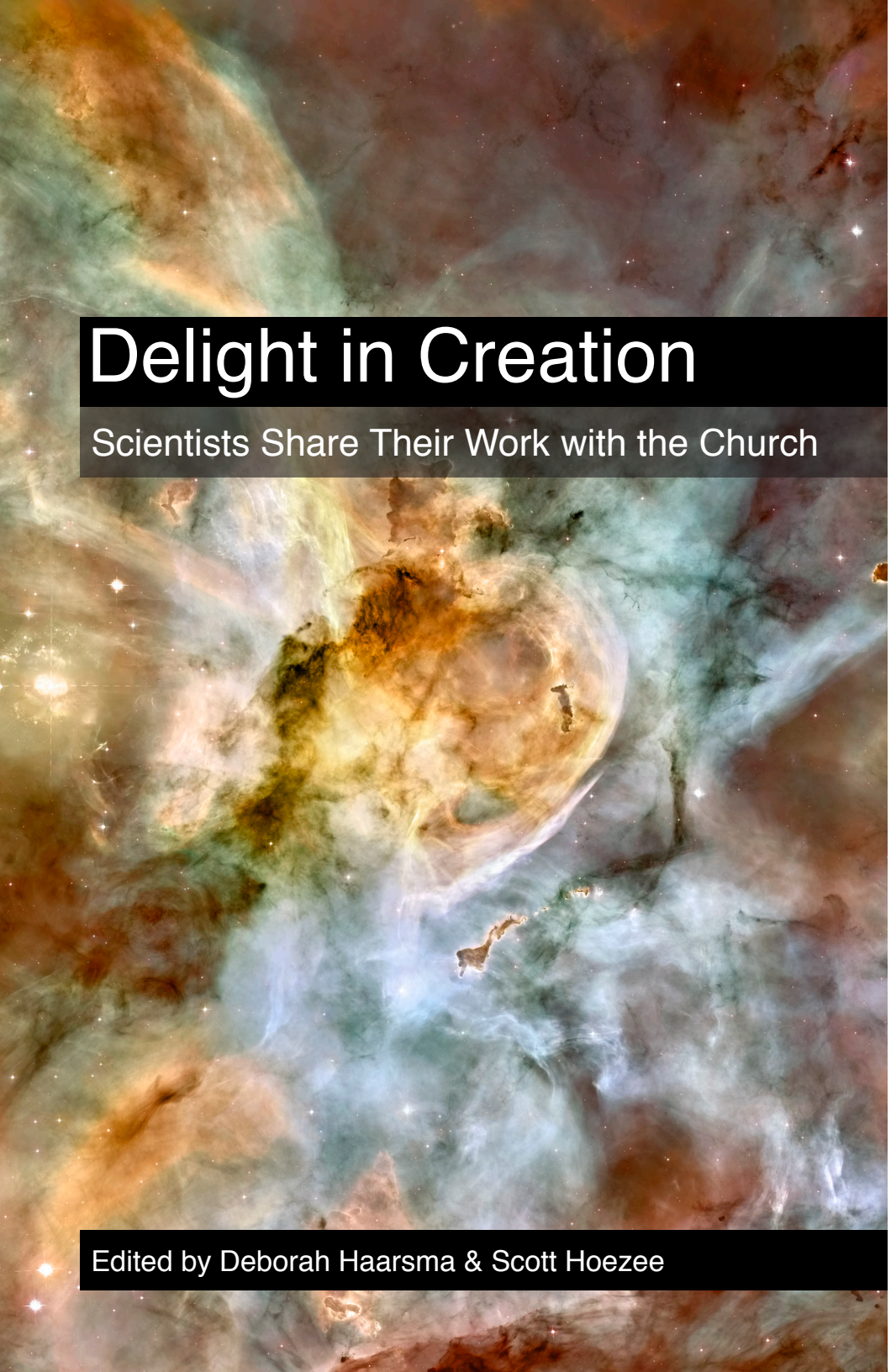

11 Rocks, Fossils and Geologic Time

by Ralph Stearley

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Lord, you have been our dwelling place
throughout all generations.
Before the mountains were born
or you brought forth the whole world,
from everlasting to everlasting you are God.
You turn people back to dust,
saying, "Return to dust, you mortals."
A thousand years in your sight
are like a day that has just gone by,
or like a watch in the night.
Psalm 90:1-4

In the United States, students learn something about rocks in grade school, usually during the fourth, fifth, or sixth grade. They learn that there are sedimentary rocks, igneous rocks, and metamorphic rocks. I've had the pleasure of giving guest lectures to children this age, and have seen terrific enthusiasm for natural history and wonderful understanding of the Earth and rocks. Unfortunately, most educational institutions do not fully develop this enthusiasm by offering geology in high school, leading to a citizenry that is largely unaware of where the raw materials for our civilization and our power sources come from, and of the intellectual and physical effort required to obtain them. We miss sharing in knowledge about the soils our crops are grown in, where our metals come from, and the geologic hazards typical of our regions. In fact, there's a fascinating history behind these everyday parts of our lives.

For thousands of years, humanity has sought the resources of the Earth: salt, fertilizers, jewels, construction materials, metals for weapons, and fuel to burn for heat or power. For example, people have mined salt in or near Salzburg, Austria, for perhaps five thousand years; "Salzburg" translates as "salt castle." People have mined copper on the island of Cyprus for at least three thousand years, and in fact, the word "copper" is synonymous with "Cyprus" in the original Greek. The oldest surviving treatise on rocks and minerals is the short work by Theophrastus, *On Stones*, written sometime around 300 B.C. Theophrastus was an assistant to Aristotle at the research institution that he founded in Athens, the Lyceum, and served

as its director for over twenty years after Aristotle left Athens. For well over a thousand years after Theophrastus, the study of Earth slowly made progress.

Beginning in the 1600s, the discipline of geology emerged as an empirical and theoretical science. In the late 1900s, geology became a planetary discipline, as missions to other planets (including Earth's moon) permitted a truly *comparative* "Earth science" to emerge. Many of the most prominent early practitioners of geology were Christians, including William Buckland, first professor of geology and mineralogy at Oxford University; Adam Sedgwick, the first professor of geology at Cambridge University; and Georges Cuvier, the founder of the discipline of vertebrate paleontology. Another prominent Christian was James Dwight Dana, professor of geology at Yale University during the mid-1800s, who created the system of mineral classification and wrote the leading minerals textbook, perennially updated by contemporary geologists and still in use.

The three types of rocks most of us learned about as children—sedimentary, igneous, and metamorphic—form in different ways and in response to different conditions. Sedimentary rocks host *fossils*. The word "fossil" has come to indicate the remains of once-living creatures (or their traces, like footprints). Investigation over the past three hundred-plus years has revealed that fossils come in groups or "suites" which reflect past ecological environments like shallow ocean floors, lowland forests, lakes, or rivers. Furthermore, the vertical placement of these suites in the rock record demonstrates a history of life.

I'll pick up my own story in the context of this history in the 1970s, when I was pursuing an undergraduate degree in biological anthropology at a large state university. During this time, I was presented with the gospel and placed my trust in Jesus Christ. I completed my degree, but at the suggestion of many friends, read a great deal of the literature put out by the Institute for Creation Research and other sources that promote a young Earth. This literature promoted the view that much of the rock record, including most or all sedimentary rocks containing fossils, was formed through the action of the catastrophic year-long Flood of Noah—a view called *flood geology*. Unfortunately, like most Americans, I had never had the option of taking a course in geology at the high school level and had

passed by the opportunity in college. I had very little personal experience of field-based geology. For a few years, I found many of the claims of the flood geology literature appealing. A choice between a secular, materialistic science and a creation-based, supernatural one seemed easy to make.

However, over several years of visiting rock outcrops, quarries, and highway roadcuts, I began to see the wealth of evidence that *time* must have elapsed during their formation. Like the early geological investigators of the 1600s, 1700s, and 1800s, I became convinced by the internal characteristics of rock bodies and their spatial relationships that the Earth is very old. I came to realize that many of the flood geology authors I had read had very little acquaintance with rocks in the field. Most were not professional geologists at all; many were trained in another technical field such as biology, engineering, or chemistry, but they knew little about rocks.

I graduated with my degree in anthropology in 1975. By 1982, I had completed some coursework in geology at my home university and had seen enough rocks to realize that I could proceed with graduate studies in sedimentary geology and paleontology. During my graduate studies, books written by Christian geologists Davis Young and Clarence Menninga proved to be very helpful to me and many of my friends. In 1992, I accepted a position at Calvin College and came to know Young and Menninga as colleagues, and in 2008, Young and I completed together a book called *The Bible, Rocks and Time*. In the remainder of this chapter, I will share with you the evidences for elapsed time in sedimentary and igneous rocks and then comment on the fossil record of life. (Although another entire paper could be written on the evidences for elapsed time in metamorphic rocks, I omit their discussion here for length considerations.)

Evidences for Time in Sedimentary Rocks

Sedimentary rocks, like limestone, sandstone, and shale, come in discreet layered packets, termed *formations* by the sedimentary geologist. Figure 1 demonstrates two very different formations from the Grand Canyon stacked on top of one another: the Coconino Formation which is a pure quartz sandstone, and the Hermit Formation which is a soft red mudstone. Rocks in these large formations are characterized by consistency in color,

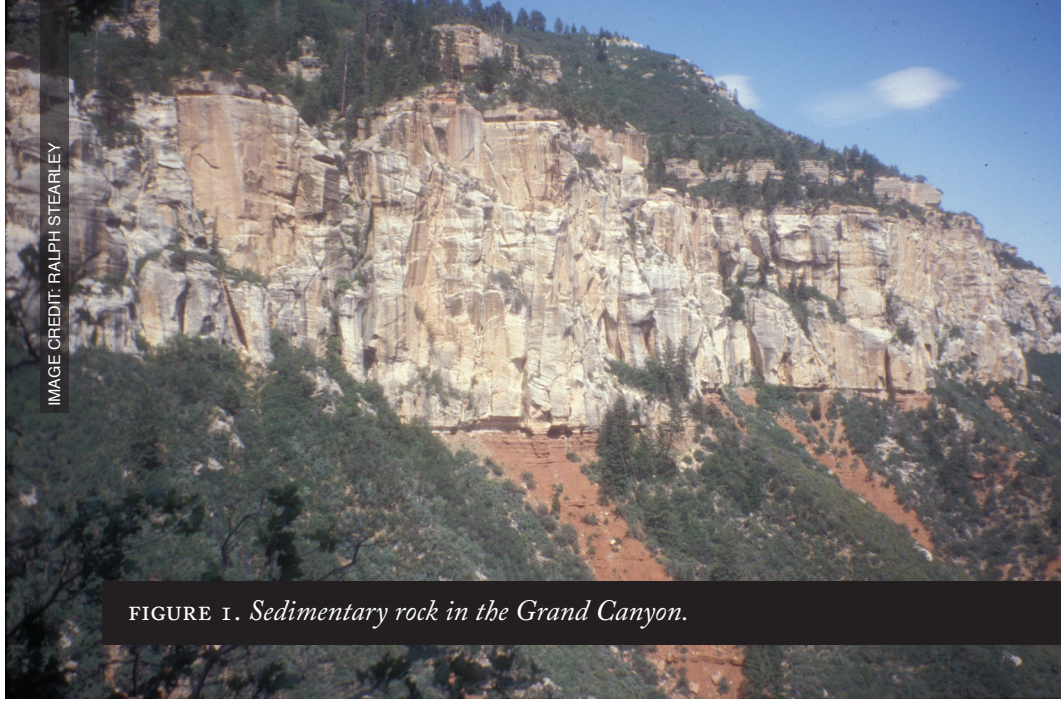

FIGURE 1. *Sedimentary rock in the Grand Canyon.*

texture, mineral content, fossil content, porosity, and physical structures like layers or ripples. Formations are separated from one another by boundary surfaces, such as surfaces that appear to have been eroded between episodes of sediment formation. Sedimentary rock formations can be consistent over hundreds of miles, and can be quite thick in total. Some sedimentary sequences, comprised of multiple formations, are around 50,000 feet thick, including the big pile of sediments on the continental shelf off New Orleans, and the thick stack of sedimentary rock exposed in mountains in northeastern Utah. In the state of Michigan, the total sedimentary sequence, including multiple formations, is typically 10,000 feet thick and gets up to 17,000 feet thick in the center of the state.

Even in flat areas, like Illinois, underground layers are well known through drilling. Information is obtained from water well drilling and, more significantly, hydrocarbon wells. As of 2005, over 800,000 wells were producing fossil hydrocarbons in the United States; there were many additional wells no longer in production. When these wells are drilled, data from the subsurface can be recovered in many ways, such as using a hollow drill bit to extract a long sample of rock. Another method is to lower instruments into the drill hole that record physical properties of the rocks,

FIGURE 2. *Limestone quarry.*

IMAGE CREDIT: RALPH STEARLEY

like electrical conductivity or natural radioactivity. Additional data come from seismic investigations, in which vibrations are pulsed into the ground and their reflections timed to measure the depths to the tops or bottoms of rock beds. Thus, when the knowledge obtained from samples is integrated with seismic data, we find that we can map the three-dimensional spatial geometry and characteristics of the sedimentary rocks under our feet.

Many shapes and structures in these sedimentary rocks show evidence of *particular events*, each requiring *time*. Such events can be of physical, chemical, or biological origin. For example, some rock formations show evidence that rocks dissolved and formed ancient sinkholes before the upper layers were deposited. Another example would be soil horizons, where ancient soil accumulated on a rock layer before sedimentation resumed to form the upper layers. Other rocks show fossil traces of roots belonging to plants, burrowing activity, or fossilized coral. Figures 2 and 3 illustrate the LaFarge Limestone Quarry in Alpena, Michigan, and the quarry wall with corals in growth position. The coral heads appear as the fan-shaped, pale-colored objects in Figure 3. The upward fanning of these coral heads is produced by budding and branching within the colony.

Long before the development of radiometric clocks for measuring ages of rocks, students of the Earth realized that 1) the characteristics of individual layers and/or their boundaries indicated that multiple, diverse events had occurred at any location, forming a local *history*; and 2) a lot of time was required for these events to occur. A single, global, yearlong flood cannot account for the many diverse kinds of events that must have occurred at a given geographic location, and it does not provide the time necessary to account for these recorded events. Geologists, theologians, and biblical scholars grappled with these realizations in the early 1800s and came up with several schemes for the harmonization of a biblical view of God's creative activity and geologic time (see the resources under Further Reading at the end of this essay for more on Biblical interpretation).

Evidences for Time in Igneous Rocks

For more evidences of time, we turn to igneous rocks. The rock basalt is a dark, fine-grained igneous rock relatively rich in iron and magnesium. If

IMAGE CREDIT: RALPH STEARLEY

FIGURE 3. *Coral fossils in limestone.*

you visit the big island of Hawaii, you can watch basalt in the process of forming from molten lava. The U.S. Geological Survey has maintained the Hawaii Volcano Observatory on the rim of Kilauea volcano since 1912, monitoring many eruptions. Lava that will form basalt upon solidifying, called *basaltic lava*, is being produced at fissures as you read this essay. Melting temperatures and flow characteristics of basaltic lava can be observed in the field, and laboratory experiments can mimic and model these actual conditions. Basalt forms at about 1,150 to 1,200 degrees Celsius. If one finds a layer of basalt that is solid and at room temperature, then that rock cooled by 1,100 or more degrees over some period of *time*.

Figure 4 shows a gorge in Washington State along the Palouse River. Several stacked, horizontal basalt layers can be seen, each corresponding to a flow of lava. As each of the layers cooled, it contracted internally, forming fractures. The fractures then weathered, to form the vertical columns visible within each horizontal layer. (Similar processes produced the Palisades cliff along the Hudson River in New York and the Devil's Postpile in California.) Thus, these columns testify to an interval of *time* during which the lava cooled. Several features make it easy to identify individual basalt flows. For example, as basalt lava flows over a land surface, gas bubbles out and forms many blatant bubble-like cavities at the top

of the flow, called *vesicles*. The tops of flows are thus marked by zones of vesicles. (In Michigan, the individual basalt flows in the Keweenaw region and Isle Royale are easily identified by vesicle zones.)

The multiple basalt layers visible in Figure 4 are part of a larger group of basalt layers collectively termed the Columbia River Basalts by geologists. These Columbia River Basalts cover large areas of southeastern Washington, eastern Oregon, and westernmost Idaho. Individual lava flows mapped within the group contain up to two hundred cubic miles of lava, spread out over tens of thousands of square miles. The Columbia River Basalts can be split into subgroups based on the chemistry of the lavas, their geographic coverage, and their connections to mapped fissures that provided the source lavas. There are geologists working in Oregon, Idaho, and Washington who have spent decades of their lives walking the breadth of the basalt layers, locating and mapping individual volcanic fissures, and drilling vertical sequences, all to decipher the history of this large packet of rocks. Time elapsed between individual flows, during which the lavas cooled to rock. In some cases, an individual flow is capped by an intensely weathered zone which was created by soil-forming processes over time; that layer in turn is covered by the subsequent flow.

During the summer of 2008, my wife and I stopped at a highway pullout southeast of Yakima, Washington, and discovered two ancient layers of basalt separated by a band of white sandy lakebeds. There were vesicles at the top of the lower basalt flow, and a baked and chemically altered zone at the contact of the upper basalt flow with the lakebeds. The upper basalt layer probably flowed directly into the lake while water still occupied the basin, but I have not been back to investigate thoroughly. I took several photographs, which I show to geology students to demonstrate evidence of elapsed time during the formation of this layer of basalt—and that is just one relatively small-scale feature contained within the huge stack of basalts in the Columbia River Plateau.

Another type of igneous rock is granite, which is used as an ornamental stone for structures like countertops and grave markers. Granite is a much more coarse-grained rock. Laboratory experiments show that granite, which forms by cooling slowly, will contain larger mineral crystals than a comparable rock that cools quickly (other factors can enter into

crystal size, but this is a good first approximation). Slow cooling times occur naturally when granite forms out of melted rock that is "squirted" or intruded into a surrounding rock body, and then crystallized at some depth within the Earth. It took geologists a few decades of deciphering the spatial relationships of granite bodies to their surrounding rocks, plus undertaking experiments involving the melting of granite in laboratories, to come to this realization.

Large masses of granite are present in the Sierra Nevada Mountains of California and elsewhere. The time required for the *production* of this vast amount of granite amounts to millions of years. The granite has *since* been uplifted to form the mountains, then exposed and eroded, requiring yet more time. And the geologic history of this region of California is much more complicated than this simple summary, requiring an even longer period of time to collectively account for all of the events in its record.

Thus, just as in the case developed for sedimentary rocks, students of the Earth realized that: 1) the characteristics of individual igneous rock bodies, their spatial extent, and their boundaries testified that multiple, diverse events had occurred at any location, forming a local *history*; and 2) lots of time was required for these events to occur—thus, a protracted local history. This history was known long before the development of radiometric clocks for measuring the ages of rocks. Furthermore, in some regions such igneous rock bodies occur *within* fossil-bearing sedimentary rock sequences, indicating that the sedimentary rock formed even earlier (these are the same sediments that flood geologists claim formed during the yearlong flood of Noah). These thick regional piles of rock show extended histories that are nested within even larger histories.

The Fossil Record of Life

During the 1790s and first decade of the 1800s, field geologists and civil engineers made a profound discovery: fossils occurred in a regular order within sequences of layered sedimentary rocks. This order was found to remain consistent over broad regions of Europe and was then discovered to extend to North America. The established order to the fossils is now known to be consistent worldwide. The empirically documented notion that fossils

FIGURE 4. *Basalt flows on the Palouse River.*

follow a particular order has been labeled the *Law of Faunal Succession*. In any given region, there will be gaps in the order corresponding to time periods in which no deposition occurred—which is what one expects when a region was not receiving sedimentary deposits during a particular time—but the remaining fossils follow the same order worldwide.

The initial discoveries leading to the generalization of the Law of Faunal Succession were made a generation prior to the publication of Charles Darwin's *The Origin of Species*. Many of the flood geology authors whom I have read since the 1970s have made the claim that the order to the fossils is contrived by geologists to support evolution, which is simply not the case. The order was documented in the early 1800s by a generation of hard-working field geologists, most of whom were practicing Christians. Many of these were emphatically opposed to the notion of biological evolution. Adam Sedgwick, for example, was Darwin's tutor in geology at Cambridge University, and while remaining Darwin's friend, opposed the notion of organic evolution. It is important to realize that this order is empirical. Thousands of amateur rockhounds and professional paleontologists can attest to it.

One often sees the claim in flood geology literature that the past cannot be examined by experiment, which is not true. As I write, I'm preparing to take a class of college students and some guests to the limestone quarry

at Alpena, Michigan, which was illustrated in Figures 2 and 3. We will perform an experiment simply by collecting fossils. I predict that we will not find any fossil alligators, dinosaurs, or reptiles of any kind. In fact, I predict that we will not find any quadrupedal vertebrate fossils of any kind. I further predict that all corals we find will belong to the extinct orders Rugosa and Tabulata and not the living order, the Scleractinea. I could add up a long list of predictions that we will test by experiment. [Note from the editor: as this book goes to press, the author reports that all predictions were confirmed — the class found only fossils of Middle-Devonian marine life.] Grade school groups, rock clubs, and college students studying paleontology repeat such experiments frequently at this particular quarry. Thus, the Law of Faunal Succession is subject to test. My own experience, obtained now over three decades of fossil collecting, is that the order to the fossil record is real. Whatever one's view on biological evolution may be, an honest appraisal of the fossil record must acknowledge this.

During the late 1800s, paleontologists who studied the history of life gradually came to accept the notion that descent of different organisms from a common ancestor was verified, but many thought that Darwin's notion of "natural selection" was insufficient to account for this history to life. During the 1900s, most professional paleontologists—but not all—have generally subscribed to a view that natural selection is important, but certainly not the whole answer to the changes in life over time documented in the record of geologic strata. While some materialistic scientists (including, unfortunately, some well-known popularizers of science) have broadcast the notion that the long fossil record indicates a huge waste, other scientists like me feel the opposite. I see instead a prolific abundance of ancient life. God's providential oversight of nature appears to involve a superabundance of kinds and numbers of living things, in which he takes delight. Yes, these creatures died, but creaturely death is an issue related to natural evil, an idea engaged by Christian theologians over the centuries. Psalm 104 and other passages from wisdom literature deal with God's design for nature's economy, which includes such items as fangs and claws. We may not understand everything, but we can trust God on what is proper for a functioning and fascinating natural world.

Why Geology Matters

The science of geology contributes to our understanding of the world in ways that are important for all citizens, both Christian and non-Christian. Geology helps us understand how rivers function and why they flood, and why earthquakes occur in some places and not others. Knowing a bit about geology can also help us understand the sources of energy for our civilization, and the economics of the exploration and development processes for these energy sources. The development and extraction of raw materials and energy sources require intellectual and physical labor. Many people are employed at these labors and deserve our gratitude for the comforts they help provide. How many of us understand how the glass in our windows was made, how the electrical wires in our homes were manufactured, or what the source of our drinking water is? Why is a penny worth more than one cent? Should the United States take the same road as France did, and begin generating most of its electricity by nuclear power? Knowing where the raw materials come from for our homes, cars, roads, appliances, and many other things can help us make good decisions on a daily basis.

The science of the Earth is really an attempt to understand how God set the planet up and the regularities with which he endowed it. Even if many geologists have other motivations, their results can tell the Christian something about creation. Unfortunately, lack of knowledge has left too many of us ill-prepared to address significant issues and analyze conflicting arguments. Over the past few decades I have discussed rocks and fossils with many Christians of diverse viewpoints, including many pastors, pastors-in-training, and para-church workers. I recently sat down with my current pastor and discussed the serious concern that many Christians feel: that the foundations of Christianity are being undercut by the insidious activities of historical scientists such as astronomers, geologists, paleontologists, and archaeologists. My pastor grew up in an area of Ontario rich in fossil-bearing limestone quarries, and thus fossils had never felt threatening to his faith (in fact, he keeps a fossil on display on his desk). He could not have predicted that, when he began his pastoral

ministry, he would find many in his congregations deeply worried by these small but elegant testimonies to God's delight in creation.

Fortunately for my pastor and others who would like to learn more about God's creation through the lens of geology, there are many wonderful resources available for deepening knowledge and understanding, including scripture and our own experiences. God has been faithful and patient, both in the long eons of natural history and in the long centuries of human history. God's attention to detail is evident in the ways he creates and sustains us as individuals. David remarked that God knit him in his mother's womb. We can wonder that God ordained that we should slowly develop in our mother's womb, then be helpless infants for years, then be trainable youths, then mature adults, and ultimately live with the Triune God in the New Jerusalem. The Bible also records many examples of God's patient slowness in redemption, including the seeming slowness in Jesus' return today! I understand this slowness as kindness. There is a wideness in God's mercy, and that wideness includes eons of time and a redemptive plan beyond our ability to imagine.

Further Reading

- Haarsma, Deborah and Loren Haarsma. *Origins: Christian Perspectives on Creation, Evolution, and Intelligent Design*. Grand Rapids, MI: Faith Alive Christian Resources, 2011. This volume is designed for use in congregational settings such as Sunday school; I highly recommend it.
- Snoke, David. *A Biblical Case for an Old Earth*. Grand Rapids, MI: Baker Books, 2006.
- Young, Davis and Ralph Stearley. *The Bible, Rocks and Time*. Downers Grove, IL: IVP Academic, 2008. Includes extensive summaries of the views of past theologians from a variety of theological and denominational perspectives.