ONE • Charles Darwin Was a Geologist

Inorganic Complexity and the Rock Record

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The Earth's fossil record records the changes in life on this planet over time; similarly, the Earth's rock record preserves complex structures that record the changes in rocks and minerals over time. Consequently, all the aspects of living things that trouble intelligent design creationists—their complexity and what seem to be the abundant traces of long and contingent evolutionary change—also apply to all the Earth's materials, whether once living or not. Therefore, one could also ask, if a supernatural power designed living things, what about nonliving things? Did the Earth's interior, crust, and surface evolve naturally, according to the material laws of physics and chemistry, or were they "intelligently designed" as well? If not so designed, why not? How do we know whether they were or weren't? Intelligent design (ID) creationists currently ask these seemingly hypothetical questions. Though geological phenomena require naturalistic/materialistic historical explanations, intelligent design creationists offer inadequate, ahistorical ones. In this essay, I use both large-scale and small-scale geologic features to demonstrate the strength of historical explanations to understand extraordinarily complex geologic structures.

In *The Design Revolution: Answering the Toughest Questions about Intelligent Design*, intelligent design creationist William Dembski writes, "As a theory of biological origins and development, intelligent design's central claim is that only intelligent causes adequately explain the complex, information-rich structures of biology and that these causes are empirically detectable" (Dembski 2004, p. 34).

However, Dembski also broadens the purview of intelligent design and states that "intelligent design is the science that studies signs of intelligence" (p. 10). So, it comes as no surprise to this geologist that Dembski opens chapter 1 of his book on intelligent design with a statement not about organisms but about rocks: "Think of Mount Rushmore—what about this rock formation convinces us that it was due to a designing intelligence and not merely to wind and erosion?" In this regard, he is not unlike the sixteenth-century astrologer/astronomer Johannes Kepler, who postulated that craters on the moon were intelligently designed by moon dwellers. Similarly, intelligent design creationists laud publication of Carl Froede's *Geology by Design: Interpreting Rocks and Their Catastrophic Record* (2007) as an "important reference text for home-schoolers" that asks "what of the rocks beneath our feet?" (Goddard 2007).

Intelligent design creationists believe that, in their words, life is irreducibly complex, and therefore could not have evolved on its own. Thus, a creator must have designed life on our planet. Though focusing explicitly on life, the traditional purview of biologists, this assertion of intelligent design creationists extends to inorganic Earth materials and constitutes an indictment not only of biology but geology. It therefore demands particularly geological responses such as the one I offer in this essay.

Over many decades, creationists have battled with and felt threatened by geologists. The arena of contention has been time. Many first-generation creationists insisted that the Earth is not nearly as old as we geologists would have it. This camp of young-Earth creationists still persists, although the numbers of campers have declined. For geological processes to operate as they clearly do, the Earth simply *must* be very old. Abundant evidence based on years of geoscientific inquiry, investigation, and peer review reveals that the Earth is approximately 4.5 billion years old. In the face of this evidence, some young-Earth creationists have morphed into old-Earth creationists, who accept the ancient age of the Earth. These believers have abandoned time as the arena of controversy. Instead, old-Earth creationists insist that life observed today as living creatures and as fossils entombed in rocks is too complex to have developed on its own over time; it must have been designed by a creator. Many of these old-Earth creationists today base their arguments on *complexity*.

Although the bulk of intelligent design creationists are old-Earth creationists, who allow ample time in Earth's history for geological processes to operate, their insistence that aspects of the natural world are too complex to have developed on their own constitutes an indictment of geology. For example, in the Grand Canyon,

the icon of geological thought, in which Earth scientists interpret one of the simplest geologic histories in the United States, intelligent design creationists see evidence of a creator (Wilgoren 2005). Far more complex geologies than that of the Grand Canyon have been studied and explained scientifically by Earth scientists. Yet intelligent design creationists resort to faith to understand this geologic feature that, although stunning, is as "simple as cake"—so simple that geoscientists and Earth science teachers alike refer to it as "layer cake geology." That intelligent design creationists see in the rocks of the Grand Canyon what they consider to be legitimate evidence of a creator suggests that we geologists really don't know what we are talking about when it comes to explaining physical landscapes, structures, and phenomena. But naturalistic/materialistic reasoning suffices to explain exceedingly complex geological features and phenomena as well as simple ones like those of the Grand Canyon. One need not employ claims about the actions of an intelligent creator to explain such physical complexity.

Geologists' explanations of complex structures are based on observations so obvious and routine that geoscientists refer to them as *laws:* the law of stratigraphic superposition (in an undisturbed sequence of strata, the oldest strata lie at the bottom and necessarily higher strata are progressively younger); the law of original horizontality (almost all strata are initially nearly horizontal when they form); the law of original lateral continuity (strata have continuous tabular shapes, "pinching out" laterally to a thickness near zero or abutting against the walls of the natural basin in which they formed); the law of cross-cutting relationships (faults and invading igneous rocks are always younger than the faults or rocks that they transect or intrude); and finally, the law of components (a body of rock is younger than another body of rock from which any of its components are derived). Our understanding is bolstered by the principles of uniformity of law (the idea that natural laws do not change over time) and the uniformity of process (the idea that the present is the key to the past). Despite the fact that these laws can guide any careful observer to provide naturalistic explanations for many of Earth's processes and the features that arise from them, intelligent design creationists have sought to develop supernatural explanations—those outside the realm of science—for various features of the Earth.

For example, though plate tectonic theory, one of geology's greatest contributions to twentieth-century science, thoroughly explains the geomorphic features of continents and oceans around the globe, creationists have developed a model termed "catastrophic plate tectonics," which allows a compressed time scale and deploys geological processes to provide a mechanism for the biblical flood (Austin

et al. 1994). As a means of finding a source of biblical floodwater, creationist articulations about catastrophic plate tectonics misappropriate numerous well-understood concepts within geology, including mantle convection (the creeping motion of the Earth's rocky mantle in response to unstable variations in its density), geomagnetic reversals (changes in the orientation of Earth's magnetic field), and geochemical processes such as evaporation and precipitation (Baumgardner 2003).

To show how one might be tempted to invoke an intelligent creator to explain the existence of complex features of the Earth at both the macroscopic and microscopic scales, I reproduce and interpret images of some complex Earth structures. At first look, each of these images presents an end product that requires a series of events that might seem impossible without the intervention of a creator. Yet, each set of features has a well-documented history confirmed in the course of the normal scientific research that characterizes the field of Earth science.

GEOLOGICAL SECTIONS

Geological sections or cross-sections show the patterns of rocks as exposed on the side of a road cut or on the wall of a trench. When interpreted carefully, they reveal the histories of sequences of rocks at or near the surface of the Earth; that is, one can infer the order of events that produced the section. In fact the essence of geology, going back to the eighteenth-century Scottish Enlightenment and the days of James Hutton, our science's "founder," is to observe rocks "in the field" and allow them to "tell their stories." To interpret the order of events in a geological section using the laws of superposition, original horizontality, lateral continuity, cross-cutting relationships, and components is to "read" the natural history of that portion of the Earth.

The complex section in figure 1.1 shows a view across New York's Hudson River in the vicinity of the George Washington Bridge. In geological parlance, it shows westward tilted strata of the Newark Basin and the Palisades sill with their nonconformable relationship to folded metamorphic rocks of New York City (Berkey 1948).

How could this complex series of contorted, tilted, and gouged rocks have formed? An intelligent design creationist might well summon the mighty hands of a creator to have upended some rocks while having squeezed and consequently bent the hardest among them, the gneiss and schist, with one hand while using the fingers of the other hand to gouge a channel along which the Hudson River now

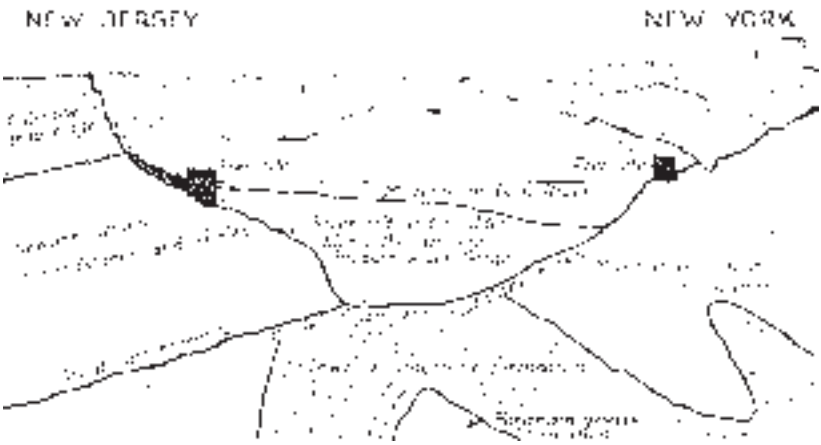

FIGURE 1.1.
Cross-section across the Hudson River between New York and New Jersey (Berkey 1948).

flows. But to capitulate to such an explanation in the name of "irreducible complexity" would deny the observer the opportunity to understand the natural mechanisms that over time would indeed have produced this section of the Earth.

Features of the Fordham gneiss, Inwood limestone (marble) and Manhattan schist formations, together denoted on the figure as the floor of ancient crystalline rocks, indicate that they originated as ancient bedrock topped by a blanket of sedimentary and volcanic rocks as many as 550 million years ago on the edge of a North American continent rimmed with volcanoes. The ancient geography of this time in Earth history was akin to today's Japanese volcanic islands rimming the coast of China. During a protracted episode of mountain building, known to geologists as an orogeny, the bedrock and volcanic and sedimentary rocks were folded and metamorphosed in a collision that ultimately produced the Appalachian Mountain chain.

Experimental and field-based studies indicate that when rocks encounter a change in pressure and temperature as occurs in a zone of collision, they fracture, bend, and generally reorganize themselves so that the mineral grains that originally formed them change their chemical compositions and physical structures. Thus the original rocks metamorphose—change their form—into rocks with new minerals and textures that only barely resemble the protoliths. Indeed this is a creation story, but it is a geological one; the rocks tell their own origin story, one that

depends only on natural processes, and we come to understand how the Fordham, Inwood, and Manhattan formations arose.

No intelligent design creationists have thus far directly challenged the veracity of this account of the formation of the basement rocks in southeastern New York State. However, their model of "catastrophic plate tectonics" indirectly condemns such an account. Catastrophic plate tectonics requires "runaway subduction" in which slabs of oceanic crust break off from the Earth's lithosphere and quickly sink deep into the Earth's mantle (Austin et al. 1994). Such rapid tectonics is incompatible with the pace of metamorphism since the recrystallization and deformation necessary for the formation of metamorphic rocks is a slow process. We know this because, for example, though diamond and graphite are both minerals made up wholly of carbon, diamond rings do not transform into graphite in anyone's lifetime; in geological parlance, they persist metastably. Thus it comes as no surprise that intelligent design creationists assert that "the initial state from which the runaway emerged was built into the Earth as God originally formed it" (Baumgardner 2003, p. 12). Nevertheless, we can explain the complexity reflected in the basement rocks of southeastern New York State using only the laws of nature.

The "great unconformity" above the crystalline basement rocks shown in figure 1.1 propels an observer forward in time into the "Newark series of sandstones and shales" and the "Palisades trap ridge." Based on its contained fossils, as well as grain sizes and compositions, we know that this package of rocks is a thick sequence of middle-aged (Mesozoic) sedimentary strata and volcanic layers. Using the laws of original horizontality, lateral continuity, superposition, cross-cutting relations, and components, as well as the principles of uniformity of law and uniformity of process, geologists have been able to discern that the Newark sedimentary strata were deposited in a basin into which seawater never flowed. They became interlayered with igneous rocks that intruded into and erupted on the sedimentary rocks in processes not unlike those that occur today in the rift zones of eastern Africa (Merguerian and Sanders 1994). This sequence of layers formed in association with the opening of the Atlantic Ocean (Olsen 1980). Faults, planes along which rocks have moved against one another, in the area indicate that huge stresses associated with the breakup in the early Mesozoic of a large "supercontinent"—known to geologists as Pangaea—produced a series of basins into which sediments were eroded from adjacent high areas. The rusted red color of some of the sedimentary layers indicates to geologists that, much as metal rusts when exposed to air and water, iron in the sediments interacted with oxygen. Thus, the basins were

periodically exposed to air when not covered in shallow water. In many places, "fossil raindrops" preserve a record of rain showers falling on moist muds (Passow 2007). The uniformities of law and process provide ample evidence for the basins' origin in erosion caused by precipitation. Evidence from fossils corroborates this interpretation: worms or other burrowing organisms left tracks, as did some of the earliest dinosaurs as well as other large extinct reptiles such as *Clepysaurus (Rutiodon)* (2007). Above these rock units rest the "river silt and boulders filling the ancient Hudson River gorge," carved through the work of water and ice in the relatively recent geological past (Merguerian and Sanders 1990). Thus, it is by reading the record of the rocks that Earth structures of enormous complexity are explained with the aid of natural laws.

PINWHEEL GARNETS AND MINERAL INCLUSIONS

Photomicrographs of rock samples are photographs of polished, very thin slices of rock taken through a microscope. They frequently reveal that the internal structures of rocks are more complex than is evident to the naked eye. Examined through the microscope, such thin sections are kaleidoscopically beautiful and resemble stained-glass windows. Mineralogists and petrologists (geologists who study the history of the Earth by examining the chemical and physical microstructures of rocks in thin section) determine the histories of rock units by detailing these microstructures and the often multiple generations of events that they conclude must have occurred to produce them.

The image shown in figure 1.2, whose long dimension does not exceed thirteen millimeters, displays a garnet grain with spiral-shaped inclusion trails (small pieces of one or more types of minerals enclosed in a host mineral) in a rock from the Appalachian mountain range in Vermont. Such garnets have been described as among the most alluring and perplexing microstructures in deformed metamorphic rocks; they look like they have rolled like snowballs in the dirt (Moore 1999). How were they formed? In the face of such tremendous complexity one might be tempted to invoke an artistic and dexterous creator. However, geologists are able to use the law of cross-cutting relationships and the law of components on the microscopic scale for textural analysis, that is, to determine in what order the minerals formed, as well as their knowledge of chemical diffusion, the movement of elements from one part of a solid to another, to outline the remarkable history of the rocks that contain them.

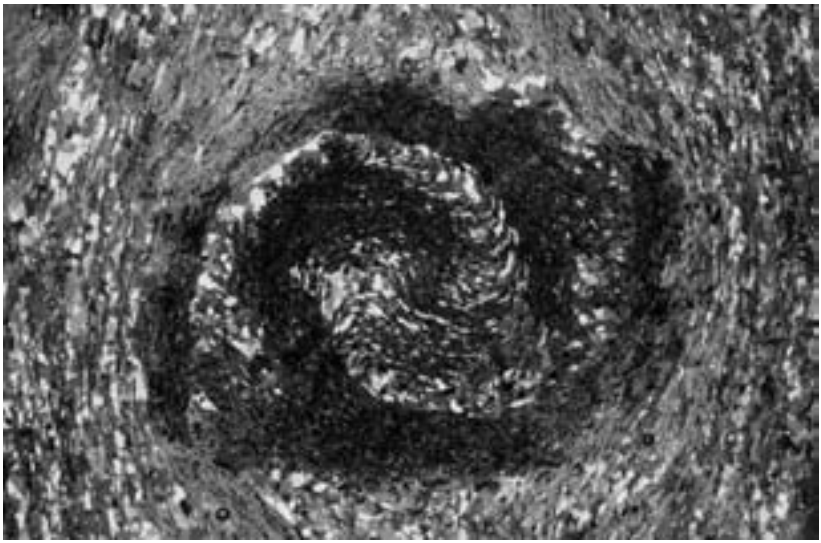

FIGURE 1.2.
Garnet grain with spiral-shaped inclusion trails, from the Appalachian mountains, Vermont (Moore 1999).

The garnet grain in this image contains curved trails of inclusions—incorporated bits of other types of minerals such as quartz and ilmenite—that look like preexisting berries included in pancakes. The origin of these inclusions has been the subject of debate among metamorphic petrologists. Some investigators believe that the mineral inclusion trails indicate that such garnet grains rotated as they grew, while others suggest that the enclosing grains rotated around the garnet crystals. The distinction is not critical because under either interpretation the patterns of inclusions suggest that the garnet grains were not created as we see them; they have a history, and clearly grew as the rocks were actively deformed (Bell 1985; Bell and Johnson 1989; Rosenfeld 1970; Rosenfeld 1987; Schoneveld 1977).

Such curved inclusion trails are a common feature of large crystals, known as porphyroblasts, in rocks from deformed metamorphic regions. They have been a source of intrigue for almost a century and, although complex, have the potential to aid understanding about metamorphic and structural processes that occur during the formation of mountains. Metamorphic petrologists and structural geologists strive to understand the metamorphic and deformation history that a rock has experienced. One problem that such geologists encounter is limited access to

information about this history. To determine the early history of a deformed rock, metamorphic petrologists and structural geologists must find "windows" as a way to look into the past.

What of the rocks beneath our feet? They are the result of physical processes that follow natural laws. As the fossil record serves as a window for paleontologists, inclusion-riddled porphyroblasts serve as windows for metamorphic petrologists and structural geologists as they enumerate the sequential development of metamorphic minerals to comprehend episodes of mountain building in the Earth's history (Johnson 1999). Similarly, geologic cross-sections serve as windows for stratigraphers and sedimentologists as they articulate the cycles of deposition, erosion, and uplift recorded in remnants of rock.

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