of its kind. The authors do a commendable job in leading their target audience of mainly nonprofessionals into topics whose technical and biological complexities are made far more understandable through the authors' sensitivities and interpretive skills. They show how scripture and science are complementary, yet both need to be understood and their nuances appreciated by Christians in order to develop biblically informed approaches to contemporary bioethical issues in the light of new technologies that affect medical care.

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History of Science

FOUR REVOLUTIONS IN THE EARTH SCIENCES: From Heresy to Truth by James Lawrence Powell. New York: Columbia University Press, 2015. 384 pages. Hardcover; $35.00. ISBN: 9780231164481.

In *Four Revolutions,* James L. Powell describes the very human process of introducing new ideas and the winnowing that occurs before general acceptance. Powell is a very accomplished geoscientist whose credentials include presidencies of Oberlin College, Reed College, and Franklin and Marshall College. He served at the request of both Ronald Reagan and George H.W. Bush on the National Science Board. Powell is a geochemist by academic training from a doctorate from MIT. He writes very well, and at a level suitable for science-literate high school graduates. The book's four sections cover the ideas of deep time, continental drift and plate tectonics, meteorite impacts (structures and ecological effects), and climate change. In each case, a compact but salient history is given, along with the names of key thinkers and the dates of importance.

In the initial section on time, we encounter the roots of the humorous (if one has a sense of humor), trite disregard that physicists, in particular, have for geology. Most attribute this disciplinary disdain to Ernest Rutherford, late in the nineteenth century. However, it actually goes back at least as far as the 1860s, when Lord Kelvin vilified the lack of temporal precision in geological arguments. Kelvin's 1868 "assault," in Powell's words, was rebutted by the then-current president of the Geological Society of London, T.H. Huxley: "Mathematics may be compared to a mill of exquisite workmanship, which grinds your stuff to any degree of fineness; but nevertheless, what you get out depends on what you put in …" Huxley also wisely stated that, "It is the customary fate of new truths to begin as heresies."

Powell continues to entertain us with tales of the efforts of succeeding geologists, physicists, and geochemists to extract Earth ages from geological materials and processes. Approximations of earth age were scattered from hundreds of thousands to billions (from Kelvin's student John Perry) of years. The advent of using radioactivity as a clock for elapsed geologic time gave the scientific community one of its true pioneers and enduring stars, Arthur Holmes. Beginning about 1908, he developed a grand array of hypotheses and brilliant time-related concepts, wedding radiometric age determinations with observed geological phenomena. In my mind, Holmes became academically immortal when he published the geology text, *Principles of Physical Geology* in 1944, a text that has never been surpassed in scope or insight. After Holmes, various researchers extended the early techniques, producing more and more sophisticated estimations of geologic time. More recent studies have really only refined the excellent foundation established after Holmes. Note that among his other accomplishments was an amazing explanation for global tectonism, a "preview" of the greater confirmation of plate tectonics in the 1960s.

Part II of the book brings global tectonic ideas into a historical context. Early world maps constructed from ocean navigation inspired conjecture about the apparent fit of coastlines, Africa into South America as a prime example. This puzzle-piece matching remained whimsy until the early 1900s. The book gives us a summary of how science is a purely human enterprise, and ideal explanations are arrived at despite many limitations of methods.

Sin, though not explicitly stated, plays a big role throughout Powell's book, in exhibiting how personalities are barriers to intellectual progress. In the case of Alfred Wegener, astronomer turned atmospheric researcher and geology "amateur," there was demonstrated bitter opposition to his (and others') concept of continental drift, for both good and bad reasons. Wegener's publications from just before and after World War I, proposed many interesting and plausible explanations for the existence of joined continents in the past. Some scientists were immediately in agreement, but other prominent geologists and physicists were not only opposed, but rudely so. Ego, perhaps jealousy, the lack of collegial connectedness (not a geologist), and probably Wegener's German nationality all slowed the acceptance of the mega hypothesis. Some of US geology's biggest "guns," such as Stanford's Bailey Willis, were brutal in countering Wegener and the concept.

Powell writes of additional pros and cons, believers and unbelievers, concerning the mobile earth, but the Wegener episode is the most significant story until the early 1960s. A wonderful boom in post-war (WWII) technology and exploratory spirit built the background

for elevating the continental drift idea into plate tectonics as the geoscience paradigm. Many innovations, including paleomagnetism, sonar mapping, K-Ar geochronology, and submersible ocean-floor vehicles enabled the development of a plausible mechanism for "drift" beyond Wegener's "guess" and Holmes's 1929 almost-correct idea (p. 98).

The third topic (Part III), meteorite impact structures, was initially controversial because such features, as we now acknowledge them, were originally proposed as "crytoexplosives," a blast of igneous origin up from deep below. The counter interpretation of "astroblemes" or extraterrestrial impacts came from careful observation of Earth structures (notably by the USGS luminary Eugene Shoemaker and maverick Robert Dietz) in comparison with those discovered on the moon in the space race days (mid- to late-1960s). Back in 1933, Columbia University's Walter Bucher had followed the lead of G.K. Gilbert, essentially attributing all crater features as volcanic. The book goes on, as in the earlier sections, to show how the old and stubborn hypotheses were worn away by multiple lines of evidence. The stage was then set for a bigger revelation to hit in the 1980 *Science* article "Extraterrestrial Cause for the Cretaceous-Tertiary Extinction" by the Alvarez father and son team. Some researchers still have doubts, but the data in support of a meteorite impact of grand proportion in the Yucatan vicinity has grown to general acceptance as explanation for the close of the Mesozoic. Powell hides little of the rancor involved in opposition to the hypothesis. The sin of pride is all too evident among academic scholars.

As the final section, Part IV brings what I perceive as Powell's main interest into focus. His heading, *Global Warming*, is chosen instead of climate change. That in itself is telling. For the first time, the book covers a controversy significant beyond the scientific. This issue continues to rage today in the public realm, even though its great support from qualified scientists establishes the key hypothesis as firmly as any of the others described. Powell begins this section by introducing us to the brilliant G.S. Callendar, engineer and amateur meteorologist from the UK. His intuition and calculations involving the atmospheric system led to the first correct correlation between CO_2 abundance and temperature regulation in 1938. Svante Arrhenius, who won the Nobel Prize in Chemistry, 1903, had already played with the same idea. Neither the modest engineer nor the famous chemist was much remembered as the significance of an altered atmosphere became a huge ideological battleground.

Powell leads readers carefully through the ups and downs of technical advances in understanding the relationship between human activity, especially the burning of fossil fuels, and the effect on climate systems. Warming is but one result of the extremely rapid (in geological reference) disturbance of the linked atmospheric-oceanic mega-system. Unlike the other three "revolutions," that of global climate change is still developing, trying to overcome opposition from political and vested economic interests (not scientific opposition). There is strong scientific support for the conclusions of the Intergovernmental Panel on Climate Change. Plainly, human beings have caused to increase and continue to increase the amount of atmospheric "greenhouse" gases, such that Earth's climate is growing hotter, less predictable in terms of weather events, and more prone to spawn events of greater severity with risk to life and property. This last of four revolutions needs everyone's attention and willingness to act for reversing destructive lifestyles.

I am aware of many books that seek to popularize the stories behind great scientific advances. Powell's book is comprehensive but not overly long. It probes the personalities involved but without sensationalism. I learned many details that contributed to my understanding as an earth scientist, and am certain that others, scientists or not, will gain interesting and useful insights in the reading. I would recommend the book for general interest as well as a potential asset for a seminar course emphasizing the history of geologic thinking.

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MATHEMATICS

MATHEMATICS WITHOUT APOLOGIES: Portrait of a Problematic Vocation by Michael Harris. Princeton, NJ: Princeton University Press, 2015. xxii + 438 pages, with endnotes, bibliography, and index. Hardcover; $29.95. ISBN: 9780691154237.

Why should we encourage people to study mathematics, and why should scarce resources be allocated for mathematical research? Should mathematics be pursued because it provides a theoretical core for technological applications that make our lives easier and better, the Golden Goose argument? But while abstract theories may one day become practical (number theory gave us modern cryptography, the basis for secure online transactions), there is no guarantee that they will ever lay such an egg. Nor is this the express motivation given for the work pure mathematicians do. Furthermore, mining mathematics for commercial possibilities can be harmful instead of beneficial—recall the crash of 2008 engineered by greedy risk-takers wielding mathematically based financial instruments. (Harris was warned away from indicting the quants who promoted the widespread use of derivatives, but chapter 4 lays out