THE AGE OF THE EARTH: SCIENCE, RELIGION, AND PERCEPTION

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Geology is a huge part of your business. You have a greater intimacy with the structure of Earth's crust than any group I normally meet. So maybe it's worth our while to talk about how we formed our perception of ourselves-in-God's-universe by studying that fragile crust.

Let's talk about how we calculated Earth's age and some of the stuff that went with the unfolding of revelations that followed as we pursued that calculation.

The old Biblical begats first came under serious assault after medieval miners began digging deeper than they had before. The history of the age-of-the-earth question is wedded to the history of mining (which, in a sense, is your business today). The problem is, the history of mining didn't exist a century ago.

We did have Georgius Agricola's marvelous book, *De Re Metallica*, but modern scholars didn't know how to read it. Agricola lived through the early 1500s, and his masterpiece came out just after he died in 1556.

Agricola, who started out as a physician in the mining region of Bohemia, was drawn to mining and metallurgy. He gave up medicine and devoted his life to mining engineering.

De Re Metallica is quite a modern book. Agricola avoided the methods of the alchemists. He wrote straightforward and accurate accounts of observed facts. He was a shrewd observer.

The book was sweepingly comprehensive. It was still the bible of mining engineers on the eve of the Industrial Revolution, 200 years later. And I mean Bible. Mining-district churches chained copies to their altars. That way, the clergy could translate parts of its Latin text for the miners in their congregations.

Now enter a most unexpected couple: Before President Herbert Hoover entered politics, he was the outstanding mining engineer of his time. In 1905 his wife, Lou, wrote to the Stanford Professor who'd taught geology to them both. Lou had run across a copy of *De Re Metallica* in London, and she wondered if there was an English translation. If there wasn't, she wanted to use her knowledge of Latin to create one.

Then the fun began: Lou and Herbert Hoover undertook the job together. They worked every spare hour from 1907 until 1912. What they produced was no mere translation.

Their introduction, footnotes, and appendices, by themselves, made up the first comprehensive history of mining ever written.

Agricola had invented most of his Latin technical terms, and the previous German translators had butchered them. Now, with extraordinary care, the Hoovers figured out Agricola's intent. They made a whole study of Latin and Medieval units of measure. Herbert did laboratory experiments to check Agricola's statements.

Together, the Hoovers took us on a guided tour through the complete mining literature before Agricola and much of what followed. These two amateur historians set down the origins of the field of mining engineering with brilliant scholarly work.

This lovely book, with its 289 fine woodcuts, tells us just what mining was like and how it was done. It presents a microcosm of late Medieval and early Renaissance life. The Hoovers' work stands today as the single classic in the history of mining.

Now: *De Re Metallica* was not a book on the secrets of nature. It was a practical tract on how to extract Earth's wealth. Agricola didn't presume to know God's intentions the way earlier writers did. Nor did he try to divine them the way philosophers would after his death.

As we dug deeper into the earth, we did trip across the question of God's intentions. Earth's contents were complex and laden with riddle. For example, come forward 150 years and meet Nicolaus Steno. Steno was born in Denmark in 1638. He studied medicine and did fine anatomical work while he was young. At 27 he became physician to the Grand Duke of Florence and also converted to Catholicism. Twelve years later he became bishop to the Catholics in the Protestant North.

Just after he came to Florence, he wrote a book on geology. The title was *Introduction to a Dissertation on a Solid Body Contained Within a Solid*. Then he joined the Church and never wrote the full dissertation.

He left scholars confused. They credit him with pointing out that angles between crystal faces are constant. But that was just an offhand remark in a figure caption. Steno had really been dealing with other matters entirely.

The new observational science had begun with people like Agricola. Steno was one of the new breed who brought that kind of thinking to fruition. He was fascinated by stony inclusions -- one rock inside another. And stony inclusions were raising a lot of questions about God's intentions.

Steno looked at inclusions with an artist's eye. He realized that there were two entirely different kinds of inclusion. In one, a hard inner substance fills a cavity in an outer rock. In the other, the outer rock shapes itself around an inner one.

Crystal inclusions and veins of metal fill rocks in. But sediment forms itself around fossils. The trouble is, no one knew about fossils in Steno's day. One inclusion looked like a seashell. Another, a vein of quartz, might be shaped like the letter Z. God had just as mystically left a seashell in one and the letter Z in another.

Steno changed all that. He saw that the two things had to have been put there by different means. He saw that the image of a seashell wasn't an image at all. It was the vestige of a real shell. He saw that sedimentary rock had formed around it.

So the world we knew began to change. Steno's Earth couldn't have been formed in one sidereal day. It was made by long sequences of events. We remember Steno for a chance remark about crystal angles. But his great contribution was putting us on the road to creating a history for Earth.

Stephen Jay Gould laments the way we read Steno today. Twentieth-century readers miss his question: "Of the two rocks -- inner and outer -- which formed itself to the other?" We grasp for direct insights like the one about crystal angles. What Steno really gave us was a whole new way of looking at geological formation.

After I recently found that the Catholic Church had declared Bishop Steno a saint, I began to wonder if they hadn't sainted him for the wrong reasons. (Certainly the crystallographers have.) But, in any case, I don't suppose that's an honor that many geologists look forward to.

Of course Gould writes a lot about the great lurch in perception that stretched Earth's age from a few thousand years to several billion. He calls it the discovery of deep time. One of Gould's favorite characters was a geological theorist named Thomas Burnet, whom textbook writers have treated badly. Technical textbook writers all too often take a pretty facile view of history. It's all too easy to make yesterday look like nothing more than ignorance of today's knowledge.

During Steno's lifetime -- in the 1680s -- Burnet wrote an important geological treatise. He called it *Sacred Theory of the Earth*. His Bible-based Earth begins as a chaotic void. He shows how it congealed into a perfect sphere -- the home of Eden.

He details rational means by which the Great Flood ruined that perfect earth when it left in its wake continents, mountains, seas, and disorder. Then he predicts what will happen. At the second coming, Burnet's earth is to be burned by fire. It is to revert to spherical perfection, and it will finally be made into a star at judgment day.

That's hard for us to take seriously. So we paint Burnet as a misguided biblical literalist. Writers have spoken of his "romantic and unprofitable labors," of "wild fancies that deserve to be called travesties!" One writer even said flatly that his writings were the sort of stuff we sweep out of stables.

In fact, Burnet exchanged long letters with Isaac Newton. They agreed on the substance of Burnet's Sacred Theory. They argued only over details. It was Newton -- not Burnet -- who suggested that we get around logical problems by assuming that God kept changing the rules of natural law during the Creation. Burnet stayed away from that sort of thing. Here's what he said:

'Tis a dangerous thing to engage the authority of scripture in disputes about the natural world, in opposition to reason; lest time, which brings all things to light, should [reveal that what we] made scripture to assert [was false].
A new observational science had grown up around Burnet. Now scientists had to go where the non-technical language of the Old Testament was never meant to go. They had to accommodate hard observations.

That's what Burnet and Newton tried to do. A century later, scientists realized that the Bible gave them a different kind of information altogether. They went on to face the fact that Earth was almost incomprehensibly old. When modern scientists finally reached that point, they overlooked the pioneering nature of Burnet's attempts to model geological time. They rewrote history to match knowledge they never had to question.

We really dishonor the inventive minds of an earlier age when we forget the process it took to get us where we are. And, with that in mind, we jump forward another century. This time, meet the Scottish geologist James Hutton. He published his *Theory of the Earth* in 1795.

In 1795 scientists were still trying to fit geological evidence into Biblical chronology. Now Hutton put forth a theory that was far less friendly to Genesis than anything science claims today. Hutton didn't extend the origins of Earth to millions or billions of years. He eliminated origins entirely.

Hutton was part of a remarkable intellectual circle. He met regularly with people like Adam Smith, David Hume, and Joseph Black at Edinburgh's Oyster Club.

Hutton and Black would go off together into the Scottish wilds. Black unraveled the mysteries of heat and cold in that forbidding northern land. He set the stage for the science of thermodynamics.

Hutton also gazed at the Scottish glens and crags -- at the eerie world that was, even then, moving Walter Scott to write,

O Caledonia! stern and wild,
Meet nurse for a poetic child!
What Hutton saw was evidence for his theory. He found formations he called unconformities -- substrata of rock standing at right angles to the surface strata. And those strata, in turn, were perpendicular to the next stratum below.

Hutton decided that Earth had been shaped by cyclic deposits of silt, formed into rock, and followed by upheaval -- the drama repeated over and over. There is "no vestige of beginning, no prospect of an end," he said. Gould calls Hutton's earth "a machine without a history." Hutton himself likened Earth to a cyclic mechanism.

So Hutton banished all history, Biblical or otherwise. Maybe he should have gone back and read Steno more carefully. He failed to see that fossils progress from one unconforming layer to the next.

Hutton's prose was so turgid that he would surely have been forgotten. But he had a powerful prophet in John Playfair, another member of the Oyster Club. Playfair wrote brilliantly about Hutton's theories. He toned down the rigid claims. Playfair forged Hutton's work into a powerful influence on future geology.

It was Hutton who first opened our eyes to the idea that time reaches back far beyond Biblical family trees. But he did it by echoing the Newtonian vision of a clockwork universe. Clockwork and clockwork thinking ruled science right up to the time of Hutton, and then it abruptly died.

A few years later, thermodynamics would tell us that nothing can ever cycle along like that forever. Modern thermodynamics was only just taking shape under the hands of Hutton's friend Black. The Second Law of thermodynamics wouldn't mature until the 1850s, but it would bring back time's utter unidirectionality.

Meanwhile, we have a facsimile set of Hutton's original watercolors at the UH Library. They show the wild, beautiful images of Scotland that fueled his vision of an eternally recurring present. When I look at those pictures I hear Walter Scott's lines:

Mountains divide us, and the waste of seas ...
And we in dreams behold the Hebrides!
I won't try to sort through the 19th-century history of weaving fossil evidence into the issue of geological time. I'll go instead to a strange sidelight on the Alpha-Omega questions that Burnett and Hutton raised.

For Gould the issue is, how did geologists come to terms with time that runs far older than the Biblical begats? By the early 1800s scientists had squared off over our ancient past.

Some thought Earth had taken its shape progressively over eons. Some believed, with Hutton, that Earth is shaped by cyclic action without beginning or end. Earth is both things, says Gould. To underscore the point he shows us two strange works of art. First, the frontispiece of Thomas Burnet's book:

Remember, Burnet showed Earth after each catastrophic Biblical event since the beginning. Then he closed the circle. He showed Earth going through a matching set of

future events that finally return it to perfection. He endowed history with a fearful symmetry.

I've already argued that Burnet was a serious scientist. He simply labored to square observation with the Biblical account. Earth evolves, he said; but it also moves in a great looping cycle. He set the stage for both parts of the debate that followed.

So Gould tells about James Hampton, a barely literate janitor. God spoke to Hampton in a vision and told him to build a throne room for the Second Coming. For 33 years he did just that.

Each night after work he shaped it from bits and pieces -- old furniture, light bulbs, beer cans. He saw beauty that we overlook.

The world found Hampton's masterpiece when he died in 1964. It's a glittering array of symbolic furniture. One hundred and seventy-seven ornate pieces are all wrought in perfect bilateral symmetry.

He poured enormous creative energy into his secret room. He transmuted junk into works of strange grace and balance. Gould first saw all this in the National Museum of American Art, and he was stunned.

Hampton's throne room was just like Burnett's frontispiece. Both tell of Earth's progressive, symmetrical cycle. Hampton's pieces do tell of Alpha and Omega. He formed them in a circle that begins and ends at the top. Like Burnet, they retell the past on the right. On the left they prophesy a future that will replay past events in reverse.

With eerie clarity, James Hampton saw what scientists had struggled to see ever since Burnet. He saw that events cycle in time. Things repeat. Day follows night. Nature displays symmetry.

But he also saw that time is directional and irreversible. It takes us from one place to another. If science tells of reproducible, or cyclic, events, it also recites our history. It tells the story of our trek through time. Science tells of things that begin and which, someday, must also end.

In any case, 19th-century Biblical scholars didn't stop using Biblical exegesis to estimate Earth's age. By 1860 a hundred or so estimates were extant. They put Earth's age anywhere from 5400 to almost 9000 years.

Meantime, geologists had started insisting that Earth was, in fact, much older. But they didn't yet have any basis for making their own estimates.

By now Joseph Fourier had written a theory of heat conduction. It was based on avant-garde math that not many people could accept. Then, in 1862, Lord Kelvin used Fourier's

theory to calculate Earth's age. And his calculation was based on a fact that'd come out of all that mining-- all that digging into Earth's crust.

Kelvin knew that Earth's temperature increases one degree Fahrenheit for each 50 feet we go into the ground. He also guessed that Earth began as molten rock at 7000 oF.

He solved Fourier's equation for heat conduction into a semi-infinite region. He found that it would've taken a hundred million years for the temperature gradient at Earth's surface to flatten out at one degree every 50 feet.

Now the fat was in the fire! The deeply religious and anti-evolutionist Kelvin had given an age that was far too young to satisfy geologists and Darwinists. But it was plenty old enough to waken the ire of Biblical literalists.

The problem with Kelvin's estimate was that he didn't know about radioactivity. Now we know that radioactive decay sustains Earth's surface temperature gradient when simple cooling would've have made it far more flat than it is.

Kelvin's cooling calculation was worthless for telling us the age of our planet. It's real value lay in the intellectual stimulus it created. The great Victorian scientists and mathematicians knew something was wrong. So they formed ranks to fight over questions of mathematical method and Biblical exegesis.

The debate went on until the 20th century. It drew in Darwin, Huxley, Heaviside, and more. When they were through fighting, at least the mathematics of semi-infinite regions had found a solid footing.

Today, modern chemical analysis tells us that Earth is 4½ billion years old. But the debate over Kelvin's calculation helped set up techniques that let today's students solve far nastier heat flow problems than he ever could: techniques for determining everything from how long it takes to refrigerate fruit to how to cool a brake shoe.

But, in a odd way, the nub of the debate with Biblical literalists was the person of Adam. If Earth was old beyond our ability to calculate, when did Adam really enter the picture? Gould talks about the problem early artists faced when they painted Adam and Eve. Should they portray them with or without navels? Adam was molded from spit and clay and Eve from Adam's rib. Neither was born of a woman, so how could they have navels? Yet they'd look pretty silly without them. Artists often dodged the question by extending fig leaves over the lower belly.

That may sound foolish, but it took on huge significance just before Darwin -- as geologists began seeing so much history written in the rocks. Navels suggested only that Adam had a history before his creation.

Now geologic remains were suggesting that Earth itself existed, alive and changing, long before the Biblical creation.

In 1857 a fundamentalist scientist, Philip Henry Gosse, addressed the matter. He published a great treatise: *Ompholos: An Attempt to Untie the Geological Knot*. (That was only two years before Darwin completely changed the conversation about Biblical literalism with his *Origin of the Species*.) Gould calls Gosse "the finest descriptive naturalist of his day." And *Ompholos*, of course, is Greek for navel. Did Adam have a navel, asked Gosse? Sure he did.

Gosse went on to list other figurative navels. The teeth of an adult hippopotamus, for example, are worn down to a chisel shape. Hippos aren't born that way, but they'd be in serious trouble if they didn't get there as they matured. They wouldn't even be able to close their mouths. So did God create adult hippos with fresh unground teeth? No, of course not.

Gosse looked very carefully at the fossil record, and it proclaimed a world with a very long history -- much older than hippos' teeth, much older than Adam and Eve. Gosse said that God had created a world with a built-in history -- just plopped it down, history and all. But it was history that hadn't really happened.

Still, Gosse said, that history is worth studying and understanding nevertheless, because God put it there. Naturally, logic like that cooked Gosse's goose. He left us with a huge looping tautology. He really bought it when he wrote that the question of history made no practical difference.

Gosse said plainly that a created world and an evolved world would both look exactly the same. When he did that, he made the scientific search for reality into a great cosmic joke. His readers filled in the obvious conclusion: It that were so, then, at best, God had deceived us. At worst, nothing was worth knowing anyway.

After that, we were ready to quit messing with specious logic and to take the fossil record seriously. We were ready to allow that Adam had a navel after all, along with all his forbears. After Gosse, we were ready for Darwin.

And so we learn. It's hard and it's step by step. Learning never occurs without our having to break down old knowledge in some way or another. One last story to underscore that point:

This one centers on the night before Christmas Eve, 1856 -- three years before *The Origin of the Species* came out. Fifty-four year old Hugh Miller, an important Scottish geologist, went to his study with a blinding pain in his head and wrote an agonized letter:

Dearest Lydia, -- My brain burns ... and a fearful dream rises upon me. I cannot bear the horrible thought. God ... have mercy upon me. Dearest Lydia, dear children, farewell. My brain burns as the recollection burns. My dear, dear wife, farewell.
Then he shot himself. That same day he'd finished correcting proofs of his last book, *The Testimony of the Rocks*. That was a lovely, ponderous old work, thoughtful, well-illustrated, with paragraphs that run to five pages in length.

Hugh Miller was raised in the 19th-century fundamentalism of the Scottish Presbyterian Church. He took up geology and, throughout his life, struggled with the account in Genesis.

In that last book he made six epochs of the six days of Biblical creation. He detailed each one with his vast knowledge of geologic and fossil formations.

It was conservative stuff by our lights: no hint of evolution and no question about the Biblical flood. Still, Miller was seen as dangerously liberal for stretching 24-hour days into geologic epochs.

He studied the size of Noah's ark and decided it wasn't big enough to hold all the species. So the flood couldn't have been world-wide. He ended this ceremony of compromise by saying, "I know not of a single truth that militates against the minutest [details of Genesis]."

He also said something that showed profound good sense. He said of people who "have sought to deduce from [the Bible] what it was not intended to teach -- the truths of physical science: they [fall] into extravagant error."

But this night Hugh Miller suffered another attack of some terrible mental illness. He suffered soul-curdling nightmares and imagined his brain was being eaten away. So he wrote that wrenching note and shot himself.

Then, with the publication of Darwin, the late-19th-century science-religion wars went into high gear, and Miller was brushed aside. Also brushed aside was creationist Hugh Miller's perfectly sane reminder that we have no business trying to turn the Bible into a science textbook.

Meanwhile, all of you have played counterpoint to this. In 1829, two years before Darwin sailed on the *Beagle*, Kentucky petroleum went on the market as American Medicinal Oil. In 1859, two years after Hugh Miller shot himself and the same year Darwin finally published *Origin of The Species*, E. L. Drake drilled the first oil well off in Pennsylvania. In the first year he took 2000 barrels of oil from it.

In 1869, while people were fighting over Kelvin's predicted age of the earth, America's annual oil production had quickly risen from 2000 barrels to four million barrels. In 1906, while the Hoovers were still thinking about translating Agricola, production was up to 126 million barrels.

And my 1911 *Encyclopaedia Britannica* includes lengthy articles on petroleum and petrology. No more trying to make the underground record fit one preconception or another of God's word. Now understanding the world beneath our feet was a market-driven enterprise. Now, at last, whatever truths Earth's crust held had to be dealt with at face value.

SOME SOURCES

Agricola, G., *de re Metallica*, (tr. by Hoover, H.C. and Hoover L.H.) New York: Dover Publications, Inc., 1950. (reprint of the original 1912 edition.)

Gould, S. J., *Time's Arrow, Time's Cycle*, Cambridge, Mass.: Harvard University Press, 1987.

Gould, S. J., *Hen's Teeth and Horse's Toes*, New York: W.W. Norton and Company, 1983, Chapter 5, "The Titular Bishop of Titiopolis."

By the way, Steno's actual title was *De Solido intra Solidum naturaliter Contento Dissertationis Prodromus*. I've translated the word "Prodromus" as "Introduction" for simplicity's sake. It is a more technical term that means something like "Introductory Discourse." Steno's book was meant to set the stage for a really heavy work.

Nahin, P.J., "Kelvin's Cooling Sphere: Heat Transfer Theory in the 19th Century Debate over the Age-of-the-Earth," *History of Heat Transfer: Essays in Honor of the 50th Anniversary of the ASME Heat Transfer Division*, (E. T. Layton and J.H. Lien-hard, eds.) New York: ASME, 1988, pp. 65-85.

Gould, S. J., *The Flamingo's Smile*. New York: W. W. Norton & Com-pany, 1985.

Miller, H., *The Testimony of the Rocks*, Boston: Gould and Lincoln, 1867 (first edition, 1857.) (See also, various encyclopaedia ar-ticles on Hugh Miller. *The Testimony of the Rocks* was published repeatedly until 1897. A modern edition came out in 1980.)