a2 Earth's age makes for an historical geology

< Hutton, Playfair >

[The Lord] hast founded the earth upon its own bases: it shall not be moved for ever and ever [*sic*].
—Psalm 103.[1]

Earth is very old. Modern historical geology depends on this truth.[2]

The truly great length of geologic time, more by far than the hand-waving few millions of years granted by some Enlightenment savants, was first announced in 1785 by James Hutton (1726-1797) at a meeting of the Edinburgh Philosophical Society, Scotland. [3] At the time, Hutton's young friend John Playfair (1748-1819), professor of Mathematics at the University of Edinburgh, believed, as did most others of Judeo-Christian education, that Earth was at best 6000 years old (the Vedic concept of cyclical time was not a consideration, nor has the notion of a day in the life of Brahmâ, a kulpa cycle of 4,320 million Earth years,[4] played any role in geology).

Hutton in 1788 took Playfair on a field trip to Siccar Point, Scotland, where he could demonstrate, from the rocks exposed, the geologic evidence for a prehistoric Earth. This firsthand experience with reading the rock record was a revelation to Playfair. Earth was indeed exceedingly old. Realizing how much more so than ever he had cause to imagine, Playfair was moved to exclaim: "The mind seemed to grow giddy by looking so far into the abyss of time." [5]

This received knowledge now replaces that which was: "The poor world is almost six thousand years old," is a line for Rosalind in *As You Like It*, first produced by *William Shakespeare* in 1599.[6] In 1619, in the introductory blurb to *Harmonices mundi*, Kepler boasts: "God himself has waited six thousand years for a witness."[7] The "Before CHRIST 4004" in the GENESIS rubric of the King James' Bible, from 1701 on,[8] airs Archbishop Ussher's magisterial reckoning, given in his *Annalis Veteris et Novi Testamenti*, 1650 (English translation, 1658), that "The creation of heaven and earth" was 6000 years ago.[9]

In 1795, Hutton published *Theory of the Earth with Proof and Illustrations* in needed response to attacks on his theory by Scriptural geologists, as in Richard Kirwan's *Examination of supposed igneous origin of stony substances*, 1793.[10] In 1802, five years after Hutton's death, Playfair (***Figure a2.1***) wrote the concise and popular *Illustrations of the Huttonian Theory of the Earth*.[11]

Now that the thoughtful could be persuaded that there is proof of prehistory, modern Western civilization could begin.

Hutton is considered to be the founder of geology.[12] Modern geology is two hundred years old.

The age of Earth as a stony body upon which familiar geological processes first began to operate is 4,550,000,000 years old. However, as no Earth rocks of that time survive unchanged, this was first calculated, but only as late as 1953 (*see* Topic *L11*), from lead isotopes in the Canyon Diablo iron meteorite (a fragment of that which excavated Barringer meteorite Crater, NM).[13] In agreement are ages found for other meteorites and for the oldest lunar rocks returned by *Apollo* astronauts. Before Earth and Moon came to be, the first solar-system stony bodies (some of the asteroids known from meteorite samples) by best estimate began to condense 4,566,000,000 years ago.[14]

Many years after the geological proof of Earth's great age had gained workaday acceptance, the invention of photographic plates and spectroscopy gave astronomers the tools they needed to measure the vastness of time independently (***Figure a2.2***). That light does not travel instantaneously from place to place was adduced by Ole Roemer in 1676 from his observations that eclipses of Jupiter's timekeeper moons are ahead or behind schedule when that planet in its orbit is closer or further from Earth. The speed of light (in miles per second to six decimal places!) was inferred by James Bradley in 1728 from star position aberrations in his unsuccessful measurements to find parallax—the first success being Friedrich Wilhelm Bessel's "Determination of the distance [660,000 astronomical units] of the 61st star of the Swan [61 Cygni]," published December 1838. In 1851, the speed of light

was measured directly, separately, by Armand Fizeau and Jean Bernard Léon Foucault (pronounced *foo-co*).[15] Modern astronomy (astrophysics) began when Angelo Secchi (1818-1878) in 1863 first observed the spectra of stars other than Sun and Henry Draper (1837-1882) successfully photographed a stellar spectrum (of Vega) in 1872.[16] In 1923, astronomers were of a mind that the furthest observed objects were within our galaxy (Gk. *galaktos*, milk) the Milky Way (now known radius 50,000 and Earth 26,000 light years from a black hole at its center).[17] Then, one and a half centuries *after* the geological finding of physical evidence of deep time was astronomical corroboration when Edwin Powell Hubble (1889-1953), using the 2.5 meter Hooker reflector at the Mount Wilson Observatory, made the 1920 Harlow Shapley versus Heber D. Curtis *The Scale of the Universe* debate mute in 1923 by resolving in the central star field (or nebula as it was otherwise then seen) of the Great Galaxy in Andromeda[18] a distantly-faint Cepheid variable. These stars (in our galaxy the closest and so brightest is by chance Earth's present North Star, Polaris)[19] Henrietta Swan Leavitt (1868-1921) had shown in 1912 are a "yardstick to the universe" (the more luminous, the slower is a Cepheid's blink).[20] For Andromeda, Hubble in 1924 calculated an extragalactic distance of 800,000 (revised by him in 1929 to "more than a million" and since to 2,500,000) light years.[21]

In December 1995, the Hubble (named to honor the astronomer) Space Telescope focused for two weeks on a single region of sky allowing unprecedentedly faint galaxies at high red shift to be imaged. This Hubble Deep Field doubles as a deep-time machine in that many a galaxy viewed is so far away that light from it has spent more than twelve thousand million years traveling to reach us and we see it as it was that long ago. Focused on by the W. M. Keck Observatory telescope atop Hawaii's Mauna Kea volcanic peak, the record in 1982 was of a galaxy so far away that in it the fluorescence of hydrogen atoms, at ultraviolet wavelength of 121.6 nanometers (Lyman-alpha emission), is seen (by charge-couple devices that, beginning in the 1970s, replaced modern photographic plates that had replaced daguerreotype[22] that, beginning in 1851, replaced the naked eye) at the visible wavelength of 492.5 nanometers. In the Hubble expanding-universe theory, its Doppler (***Footnote a2.1***) redshift is 5.64 which places the galaxy at 12.26 billion light years away. That has been bested (and more distant, so older, will surely be found) by the Keck II Telescope observation in 2000 of a galaxy with a redshift of 6.56, its light having traveled at its speed in a vacuum of 299 792 458 m/s which is a foot per nanosecond (billionth of a second) or 186,000 miles (300,000 kilometers) every second for 13.6 billion years. (*Note*: in scientific usage, one billion equals 10^9, which is one-thousand million.)[23]

So, although Earth is ancient, astronomers today place it in a universe that is far older.[24] Using supernovae (SN 1a type, each a thermonuclear explosion of white dwarf star) and quasars as light candles, and from the red shift of these and of the galaxies in which they were, the evidence (discounting the physicist's joke that the fundamental equation of astronomy is that 1 is approximately equal to 10) is that the luminous universe began 13.7 billion years ago to a purported (***Footnote a2.2***) accuracy of +/- 0.2 from a study of the cosmic microwave background (CMB).[25] And this can only be an underestimate. Confounding the astrophysicist's "youthful" (that is, "early") universe, is infrared evidence in 2003 that the real one is populated by "already then" mature, galaxies (many massive and some spiral). Also, stars in the halo of the Milky Way (our galaxy) have radiometric ages that, beginning in the 1960s, Pierre Demarque and others found to be of the order of 17 to 18 billion years old. However, in 1998, the Hipparcos satellite parallax measurements found that, at least, nearby stars are somewhat further away (and so are intrinsically brighter and theoretically younger). The oldest stars of our galaxy are now reckoned to be 12 billion years old.[26]

Geology is a study of Earth as a stony body. On Earth, geological processes began to operated 4.55 billion years ago. These, at variable rates and in combinations, have geologically evolved Earth and, as a guide for us to know of their magnitude and severity, they have never exceeded the ability of evolving life, that had soon developed and became a player, to survive. A metaphor for that realization is Gaia (*see* Topic *a3*).

Geology requires, and develops, a visceral appreciation of the enormous duration of prehistory as does no other science. We will begin at the now and work back into the past. ❑

Footnote a2.1 Johannes Christian Doppler, a professor of mathematics in Prague in 1842 announced the *Doppler effect* with respect, not to sound, but to starlight. (Its application to acoustics was confirmed in 1845 in Utrecht by Christoph Hendrik Diederik Buys Ballot who used a railway car full of trumpeters to achieve the expected effect of fall of pitch as they passed.)[27]

Footnote a2.2 Suspect in the light of statements in 2003 as: "Ninety-six percent of the Universe is stuff that we've never seen," crows Michael Turner in reference to NASA's Wilkinson Microwave Anisotropy Probe satellite findings that have set ratios (revised)[28] for the composition of the cosmos: 23 (26)% dark matter and 73 (70)% dark energy, leaving only 4% for galaxies, stars and people. This "is a giant leap forward in credibility for cosmology," exalts Max Tegmark. "What we need now is a good story," returns Turner.[29] And optimistic Brian Greene in his readable *The Fabric of the Cosmos*, 2004, tells one in which a Big Bang is a "no-braner" and a Big Splat is a "p-braned" possibility.[30] As to that, "Not even wrong!" snaps Peter Woit using Wolfgang Pauli's phrase.[31]

Figure a2.1 **John Playfair** (1748-1819)
Upon the death of his friend, James Hutton, Playfair began to compose a biographical memoir (published in *Transactions of the Royal Society of Edinburgh*, 1803). In the course of its preparation Playfair saw a need to counter criticisms by Neptunists, as Jean-André de Luc and the vociferous Richard Kirwan,[32] of Hutton's deistic notions that had inspired him to find geological proof for an exceedingly old, yet ever ongoing, Earth with evident cycles of physical renewal supportive of life's continuance. After five years of geologizing, Playfair had generated the text of a compelling geological treatise: *Illustrations of the Huttonian theory of the Earth*. For immediacy he used British examples and he contributed original observations that "rivers have, in general, hollowed out their valleys."[33] He also explained erratics as boulders that had been transported into place by glaciers at a time when the same were thought to be evidence of the Noachian Flood 2348 BC (Ussher, 1650).

The importance of Playfair's role in the birth of modern geology is widely appreciated. H. Playfair, in his *The Playfair Family*, 1984, well says of *Illustrations*: "A work for which luminous treatment and graceful direction, stands still without a rival in English Geological literature." [34]

Figure a2.2 **The Cartwheel galaxy** is located 500 million light-years from Earth. This galaxy began as an immense cloud of hydrogen gas and dust. Then a small galaxy must have sped though it. That collision sent shockwaves outward that birthed billions of stars in their wake. The ring of stars that we see today is traveling outward at 320,000 kilometers per hour. By reversing the motion, we realize that the ring has been expanding for 200 million years. At the ring's forefront are the bluest stars; newest as such stars have short lives (10 million years for say blue Alnitak); closer to the core are redder stars; older as such have long lives (10 billion years for our green 5,778 kelvin G2 Sun).[35]

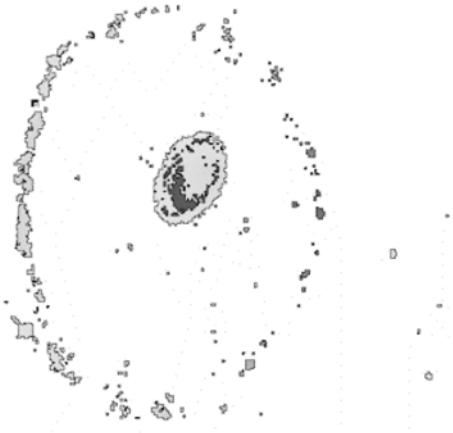

Figure a3.1 **James Ephraim Lovelock**, at age 80
Between the "cold certainty of purposeless atheism or an unwavering belief in God's purpose ... we can put our trust, even faith, in Gaia." [1] Ardent rhetoric in his first book on Gaia, "more a love letter than a textbook," appealed to those who yearn to revivify such as the Druid mother-goddess.[2] Since, Lovelock has worked to legitimize Gaia as *Earth Systems* science.