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Anthropic Rock: a brief history

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Abstract. Stone tool-making is a reductive process. Synthetic rock manufacturing, preeminently an additive process, will not for-ever be confined to only the Earth-biosphere. This brief focuses on humanity's ancient past, hodiernal and possible future even more massive than present-day creation of artificial rocks within our exploitable Solar System. It is mostly Earth-centric account that expands the factual generalities underlying the unique non-copyrighted systemic technogenic rock classification first publicly presented (to the American Geological Society) during 2001, by its sole intellectual innovator, James Ross Underwood, Jr. His pioneering, unique exposition of an organization of this ever-increasingly important aspect of the Anthropic Rock story, spatially expansive material lithification, here is given an amplified discussion for the broader geo and space science social group-purpose of encouragement of a completer 21st Century treatment of Underwood's explicative subject-chart (Fig. 2).

1 Introduction

When James Hutton (1726–1797) stated in 1788 there was "…no prospect of an end…" for Earth, he meant there were then no measured indications of our planet's eventual absence from this particular Solar System, not that it was an eternal object timelessly existing in the Universe's volume of vacuous space (Stewart, 2010). Of all places, seemingly vacuous universal space alone can appropriately be perceived as a true "wilderness" where, before 4 October 1957, there were no material artifacts of human existence; extraterrestrial space alone is the last vast apprehensible place where humans are yet primarily not surrounded by things they have fabricated. Eventually, after billions of years of "Geological Time" have elapsed, the whole Earth could become engulfed by the expanding solar photosphere when the Sun reaches its forecasted Red Giant Branch phase of the Hertzsprung-Russell Diagram (Iorio, 2010). Then, the Earth, finally, will vaporize into a barely palpable boiled-off smoke-like end-product – an Earth vaporized terminates the residence time of all of its planetary materials and propels them into interstellar space. For many coming revolutions about the Sun, Earth will surely endure predictable as well as surprising global change (Dutch, 2006) yet, ultimately, Earthly future "Geological Time" likely ends naturally or, possibly, artificially (Cathcart, 1983). Thus, George Hoggart Toulmin (1754–1817), who once did vigorously assert the eternity of Earth, and presumably the other then-known Solar System planets too, is now all but forgotten by geoscientists, his once-popular public opinion dismissed by moderns as useless rhetoric.

Founded in 1807, The Geological Society of London is the world's oldest geoscience-focused human social group. On 19 February 1830, in a lecture to the group's attending membership, Adam Sedgwick (1785–1873) admonished geoscientists to foreswear hyper-environmental futurism and not "…to speculate about the physical revolutions of the ages which are not yet come" (Sedgwick, 1834). The irrefutably direct precursor to all global contamination and pollution is the solid litter from our ancient progenitors' stone-knapping industry (Faisal et al., 2010); today's personal computer wireless mouse resembles in its most industrially useful, aesthetically pleasing form the knapped dead animal dressing tool-blade first wielded by our ancestors some 35 000 to 50 000+ years ago! Probably, stone tools were the first "ingenious devices which have been conceived and produced to serve a variety of human interests" (Harms et al., 2010). During 2011, about 20 tonnes of rock-derived materials per person per year is utilized: for a near-term future human population of 10 billions living at a high standard of living, the consumption rate would be $\sim 2 \times 10^4$ kg annually, or ~100 cubic kilometers! Nowadays, however, geoscientists are charged with the daunting task, a very challenging goal, to try to understand the past, present, and future behaviour of the whole Earth. As planetary passengers – the

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determined if sometimes rather disorganized crew of "Spaceship Earth" – our resolving species has reluctantly assumed the arduous task of safe disposal of our most enduring industrial discards, trash such as extremely high-level radioactive wastes, quite unlike the Earth at Oklo, Gabon (Kikuchi et al., 2010). 21st Century geoscientists and the world-public are acutely aware solidifiable Earth-atmosphere gaseous pollutants are an industrial survival macro-problem (Zeman, 2007; Bell, 1993). Indeed, armed with steel and concrete, the USA macro-engineers have sought – literally – to stabilize geologically a whole mountain in situ (Yucca Mountain in the State of Nevada) to contain long-lived radioactive wastes. That is why government agencies worldwide have sought, and in many instances been granted, broad mandates to humanely codify internal dosimetry, toxicology and atmospheric chemistry (Mickley, 2007). Since coinage of "geochemistry" in 1838 by Christian Schonbein (1799–1868) – he was the discoverer of ozone[1] – such interest has been extended logically to other bodies in this increasingly better understood Solar System. Unquestionably, *Homo sapiens'* most important task, and that of many of its ever-more robotized machine creations as well, is mind-endowed biological life's preservation (Sagoff, 2008; Raudsepp-Hearne et al., 2010; Piersma and van Gils, 2010; Cockell, 2011).

Proponents of the so-called Medea Hypothesis (Ward, 2009) suggested that Earthly life, eventually, eliminates itself and, further, that the Earth then enters a new period of Geological Time: perhaps the "Anthropocene" (Zalasiewicz et al., 2010) terminates suddenly and the following, barely opened, "Kerocene" transitions rapidly to a "Kenocene" period (Prosh and McCracken, 1985)? (The current global resource production economics of assiduous "rare earth" mining for electronics is an informative indicator of the state of the "Anthropocene"!) Inspired by viewing the tiny creature-deposited famously white chalk cliffs of Dover at Dartford, England, scientific microscopy was initiated by Antony van Leeuwenhoek (1632–1723) in AD 1667. The scope of this undoubtedly impressionistic essay, even as fairly well documented as it might appear remains still very broad and definitively future-oriented, necessitating a rather unusual explanatory approach that is crafted in hopes of attracting other geo and space-science historians to the hard task of writing a *compleat* Anthropic Rock account!

[1]More than 75 years ago, UK geophysicist Sidney Chapman (1888–1970) proposed in "The gases of the atmosphere", Q. J. Roy. Meteor. Soc., 60, 127–142, April 1934, that astronomers could do ultraviolet measurements better if artificial ozone holes were chemically punched in Earth's atmosphere above observatories. Nowadays, it is known that global rocket launches have a depletion effect on the planet's ozone layer (Ross, 2009). Much has been published since the 1980s on the topic of the polar region ozone holes (Mulder, 2005; Morgenstern et al., 2008; Newman et al., 2009). Active geophysicists think that expansion and contraction of these holes are also directly affected by extra-terrestrial cosmic rays (Lu, 2009). Significantly for this expose, CFCs can, literally, be inexpensively transformed into a storable, mineralized deposit (Burdeniuc and Crabtree, 1996). Unlike Egypt's open-air Great Sphinx, deposits must never endure subsequent sub-aerial weathering – i.e., deposits must be packaged (Punuru et al., 1990), possibly in resistive but corrodible concrete wrappings (Lambert et al., 2009).

2 Lithic technology, pre-historic and historic

From 1889 until 1960, civilized people used an alloy bar (of 90% platinum and 10% iridium) kept indoors in a secured vault at standard atmospheric pressure as a unique physical definition of length, the meter. Supposedly, the meter-bar represented one ten-millionth of the length of the geographical meridian through Paris, France, from the North Pole to the planetary Equator. The bar's symbolism as a tool is extraordinary: somewhat marvelously, it denotes a marked contrast with the pre-historic period of *Homo sapiens'* existence when humans lived mostly surrounded by natural things, especially lithic technology, the array of styles and techniques employed by intelligent humans to produce useable tools from various natural stones. The first step in stone-tool making necessarily involved mining shortly followed thereafter by hammer utilization in a controlled manner to successfully achieve flint-knapping results. Stone-tool making technology was needed for human survival – the acquisition of food: knapping tools, projectile points, scrapers, axes, daggers, sickles – all these, and more, were required by humans to ensure provision of adequate and consistent shelter and food supply necessities. From (Earthly/earthly) Nature, many types of natural stone were harvested by physical transactions completed by humans: chert, flint, quartz, agate, diorite, schist, jasper, sandstone, greenstone, quartzite as well as two outstanding volcanic rock types, basalt and obsidian. Geo- and space scientists, normally, explain the Earth's natural rock cycle in classrooms as commencing with erupted igneous rock, which often is found near active and dormant volcanoes. Reductively carved stone tools are, still, used today by some isolated peoples living in marginal landscapes. Later, when some metallic tools also became available, megaliths were hewn and stone cairns, walls and standing stone monuments were fashioned and installed in Europe and elsewhere on the surface of Earth. Therewithal mud bricks, some shaped stone blocks, may possibly have been included in Mesopotamia's infamous Tower of Babel (Genesis, 11:3–4, The Holy Bible).

Previously mentioned (Sect. 1), the report by Steven Ian Dutch (2006:122) voiced in print one generalization that is outlandishly incorrect: "It is ironic that one of the human structures most likely to endure for a million years is also one of the oldest: the Pyramids". The ancient Roman writer Ovid's maxim from *Metamorphosis* certainly applies – "*tempus edax rerum*" [time devours everything]. The thousands of dressed stone blocks comprising the world-famous ancient Egyptian pyramids are "cultural stone" or "engineered

stone" and, thus, far more likely to decay to structural ruination quicker than in situ natural stone (Klemm and Klemm, 2001). A half-century ago, the marine geologist Kenneth Orris Emery (1914–1998) measured the actual physical stone decay rate of the Great Pyramid in Egypt. Then, he calculated that "...the pyramid, while not eternal, may remain as the last of the seven ancient wonders of the world for 100 000 years to come" (Emery, 1960). However, Gregory A. Pope and his colleagues (2002) opined that "He did not remark, although we can speculate, on whether it would be recognized as a pyramid during this protracted time!" Therefore, Dutch is profoundly incorrect when he claimed any human-made pyramid situated in a desert will exist still in one million years' time. The pyramids of Egypt, by their shape alone, are thought to symbolize the Sun's rays and to serve as a proclamation of emerging political power in a young and territorially expanding nation-state. At the time of their construction, circa 2800 BC, the northern pole star seen from Egypt was the 3.6-magnitude Thuban (Alpha Draconis), which won't return to that visible status again until 22 400 AD. The ~150 m-high Great Pyramid was humanity's tallest stable structure for nearly 4000 years of recorded history. Many controversies center on the Great Pyramid – its true purpose, its piled structure, and even its basic stone components. For example, a French concrete chemist, Joseph Davidovits, proposed in 1974 that ancient Egyptian pyramids were built of inorganic polymer, a geopolymer "concrete" poured into molds, rather than quarried blocks of limestone and sandstone (Barsoum, 2007). This particular additive controversy remains definitively unresolved to our day (AD 2011).

Circa 21 October 1824, when Joseph Aspdin (1778–1855) was awarded UK Patent #5022 for his "Artificial Stone", concrete first became a material potentially capable of encasing the entire planet crust, its free air and everything else (Cathcart and Cirkovic, 2006; Fernandes, 2010).[2] Subsequently, nearly two centuries later, for the generally spatially confined *Homo sapiens* civilization retaining the same extendable vocabulary of this rather prosaic, plain word ["stone"] now realizes that "...concrete...[became a fundamentally]...uninterruptible resource much like energy and oil and food itself" (Palley, 2010)! The ubiquitous and massive global yearly production of cement (>2550 megatonnes, or ~1 km^3) has since become, circa 2011, of such commercial and social importance to the world of the anatomically modern human that if it were suddenly to halt no other known anthropogenic substance could supply its place, and such an event could not be looked upon in any other light than of a widespread civilization calamity for humans! Cement manufacture is responsible for ~5% of total anthropogenic carbon dioxide gas emissions and ~7% of industrial fuel usage (Boesch and Hellweg, 2010). A large area of New York City was coated by, in part, cement/concrete dust derived from the falling debris of the World Trade Towers after the 911 terrorist attacks (Depalma, 2011; Glaeser, 2011) – one might say the stratum was a unique geological layer, laid rapidly as aerial fallout. Approximately 4 km^3 of concrete is commonly poured annually. "Concrete block structures are a common sight on Mexico's landscape. Roughly 70% of the country's urban houses and an increasing number of rural dwellings are composed of blocks" (Fry, 2008). At the other end physically of the visible scale, ~100 tonnes of synthetic diamonds are produced yearly and the plasma deposition of thin diamond films, as pioneered by persons such as nano-engineering geo-material science expert Rustom Roy (1924–2010), adds to human civilization's sturdiness, perhaps enveloped indestructibility. Artificial gemstones, especially since the early 1930s, are commonplace. (Manufacture of "stones" obviates any real need for "blood diamonds" or "conflict diamonds": nowadays law enforcement officials must, however, vigilantly contend with the illicit flows of "conflict minerals" (cassiterite, wolframite, gold and coltan), essential sources of elements needed for modern electronics (Hazen, 1999; Nassau, 1980).)

[2]With correct pre-treatment, the prefabricated concrete panels proposed to enclose Earth won't repeat the sad events occurring at the 204 000 m^3 Biosphere 2 facility in Arizona, USA, where some of the carbon dioxide combined with the calcium in the concrete comprising the foundation used to construct Biosphere 2 to produce calcium carbonate. In effect, the oxygen present in the 1air inside Biosphere 2 at its closing became, over time, reduced because the atmospheric oxygen was locked up chemically in the walls and base of the structure and because of the activities of bacteria! About a year and a half after Biosphere 2 was "sealed" and occupied by eight humans, the ambient air's oxygen content fell from its initial 21% to ~14%. Combustion is severely limited, even made nearly impossible, when air has <15% oxygen content! Biosphere 2 was sealed in 1991 and unsealed in 1993 (Cohen and Tilman, 1996). The whole Earth-surface macro-engineering episode merely duplicates, on a smaller geographical scale, what actually happens to our planet at a much larger spatial scale (Nilsson et al., 2008; Catling and Zahnle, 2009). Overall, Earth's aerial oxygen content has fallen ~0.02 to 0.03 per cent since humanity's Industrial Revolution began in the mid-18th Century. Interestingly, Claude Levi-Strauss (1908–2009), in his famous memoir-travelogue *Tristes Tropiques* ["The Sad Tropics", 1955:155], with regard to urban region definition, stated: a city is "a congregation of animals who enclose their biological history within its boundaries and at the same time through their every conscious action mould and shape it. ...It is at one and the same time an object of Nature and a subject of culture...the supreme human achievement". An ideal environment, with dust and bacteria content controlled adequately, could be developed that makes impossible for any variant of the "sick building syndrome" to happen. Personally, I cannot object that some enclosing panels may, like fresh concrete deposited to make a street sidewalk, ultimately display inscriptions stick-scratched by joyful, if mischievous, children.

But, before patented cement/concrete, there were other (unpatented) artificial stones composed of processed soil (Landa and Feller, 2009) and particulated mined rock: brick, slag, glass and ceramic – indeed, it is the attractive exploded artworks of the grassroots ceramicist Steven Robert Tobin (born 1957) that seem to exemplify best, both geoscientifically, artistically and technically, humankind's ages-long recorded craftsmanship history to unnatural stone working – flaking, molding and otherwise shaping (Grande, 2007; Mansfield, 2005; Bell, 2008). The use of glass containers made it possible for humans for the first time ever to envision a vacuum – that is, to discover, see the "nothingness" and manipulate the very essence of outer space itself (Connor, 2010)! Glass heated melts; glass cooled to absolute zero (−273.15 °C) also liquefies (Markland et al., 2011) due to invisible quantum fluctuations! Since all materials are naturally radioactive to some extent, so are all wastes and all art; Tobin's artwork seems to display an classroom-like Earth globe nearly shattered by some inner, almost atomic in nature, rupturing explosion revealing the planet's various geological strata. Human ability to garner optimum performance throughout the design-life of any facility within a minimum design-life cost requires our species to excel at infrastructure maintenance, and such amenability demands uncompromising understanding of durability, sustainability and serviceability. A massive, inert and scrupulously conserved reinforced-concrete pylon, emplaced during 1908 in an urban parkland with absolute geographical co-ordinates located precisely on the Tropic of Cancer in Asia, continues to measure ongoing natural change in the Earth's obliquity because it is maintained well by those who appreciate its vital geoscience data-revelations (Chao, 1996).

3 Gamut of main, unfamiliar technogenic rocks

Each year ∼3.2 km^2 of new seafloor Earth-crust is extruded (Stern and Scholl, 2010) – that is only 1/336-th of the land area annually made impervious, largely by imbrications of concrete and other similar hydrophobic materials, to liquid surface freshwater runoffs in the USA (Theobald et al., 2009)! Today, some geoscientists believe the Earth-biosphere is becoming just an electronics-shaped human workplace, perhaps conceptually not so different from a Beta-version Windows 9 personal computer platform; Microsoft Corporation first sold publicly its MS-Disk Operating System, Windows 1.0, on 10 November 1983, now more than a quarter of a century past. Wikipedia has this year (2011) celebrated its decade of existence as a site in the World Wide Web. A metaphor comparing unrecognized or apprehended stealthy electronic entry vulnerabilities in personal computers to the fatal breach as "The Great Wall of China" might seem an exaggeration, but advancing technology and programming techniques can dynamically over-balance the scale toward the invader as well as the defender (Thelander, 2005). An instrumental operating doctrine has been deployed for Nature. Warnings issued by social scientists first emerged during the late-20th Century that humanity's remarkable current physical disconnection from Nature will permanently skew the "base-line" of what our species perceives as the entire human experience of the Earth-biosphere (Kahn et al., 2009). Moreover, for all of human existence the only means of intra-species cross-generational communication was chemical; that essential process has lately been supplemented by uncorrupted electrical information transfer, "saved" as memory, which is becoming as sturdy as pure deoxyribonucleic acid (DNA). Interestingly, the first calculators were discrete rocks, "calculus" is the Latin word for "pebble", and our species' first living computer-persons made calculations by rearranging pebbles. Knowing this, is it so difficult to imagine why remote planetary surface probe operators jubilantly rejoice on live-feed international television broadcasts over telltale pebble and boulder finds on the Moon and Mars surfaces? Sometimes misused, Nature has been instrumentalized and partially mastered for human betterment.

"The constructive process has a special place in human thinking because it is *self-certifying*" (Kirsh, 2010); thus, macro-engineering easily qualifies as humanity's self-approval psychological and physiological mechanism! To cite an example from earlier, pre-electronic supercomputer times, why else laboriously put together accurate physical orrerys as implements? From the moment when we navigate a playpen or explore our neighborhood aboard vehicles, we commence becoming exploratory geoscientists and, even, outer-space men/women in spirit; Harold Leland Goodwin (1915–1990) opined that during the late-20th Century more people studied geoscience, bioscience and space science than ever before. The ancient Greeks, amongst other intriguing mechanicals in their possession (Paipetis, 2010), indisputably constructed complex calculators, perhaps best exampled by the fabulous, bafflingly complex "Antikythera Device" (Marchant, 2009). For Charles Babbage (1792–1871) associating the operations of his clanking pre-electronic physical calculating machines to the operations of the whole planet Earth "was no mere analogy" (Dolan, 1998); electricity use is human technology's emblem of progress and, furthermore, ∼65% of worldwide electricity use – i.e., about 11.7 terawatts out of a total 2010 human civilization use of ∼18 terawatts – is by industry's "motor systems" (Worrell et al., 2009); as of circa 2009, "an estimated 330 terawatt-hours of energy. . . was consumed to operate data centers worldwide" (Meijer, 2010). Humans alive now speak 3000+ languages but, worldwide, there are only two systems of electrical grid voltage and but one coordinating universal time (Universal Time)! 20th and 21st Century science/Nano-engineering is promoting the injection of miniaturized machine intelligence into everyday and extra-ordinary useful material objects: the first solar-cells (made public circa 1954) powered Vanguard 1 in 1958 and the extra-Solar

System space probe Voyager 1, the man-made object farthest from the Sun launched in 1977, is still powered by its thermo-electric generators fueled by plutonium-238 dioxide spheres encapsulated in an iridium shield-container, instead of spatially-limited utility solar-cells (Pyne, 2010).

During the multi-billion-year existence of Earth so far, the gravitationally-bound planetary mineral kingdom has changed from simplicity to complexity just as life has changed; mobile life has pushed Earth-biosphere conditions even farther than the formation and differentiation of the planet's diverse solid materials (Hazen and Ferry, 2010). For only a relatively short period of Geological Time has life actually co-evolved with the mineral kingdom's diversification, especially the explored and measured Earth-surface manifestations of eventuating basic processes; however, possibly >50% of the extant mineral species are directly attributable to life's existence! So, extension of repairable cements and reinforcements to anticipated future human colonies on the Moon and Mars – rather like the Earth-ocean's coral structures (bioherms) or termite mounds on land – might bring this event-process to other celestial body surfaces during the 21st Century (Directed Interplanetary Panspermia Hypothesis). Meanwhile, humans within the Earth still enjoy, as they have since circa 1975, the meaningless pleasure of owning a Pet Rock: when first commercially introduced by Gary Dahl, Pet Rocks were Nature-made small boulders collected from Mexican beaches but, since circa 2009, they are manufactured by i-Star Entertainment as uniform factory-products composed of some proprietary rock-like simulant material.

Whilst unreferenced by Hazen and his colleagues, previously Harry Donald Goode (1912–2000) had already coined the usefully vague term "geoevolutionism" and had presented his precisely useful insight to the meeting in Salt Lake City, Utah, in 1969 during the very year that two male humans first walked upon the Moon's desolate regolith and commenced to shove its crust materials around (Goode, 1969; Anon., 2000). By "geoevolutionism", Goode implied that mineralogical and geological processes and major events throughout Earthly Geological Time changed markedly and that new geologic changes fostered new geologic processes that, in turn, brought about new changes. The unpublished espoused ideas he vigorously presented to that convention grew out of his attempts to reconcile the doctrines of Uniformitarianism and Catastrophism. In an astonishingly real sense that serves geo- and space scientists well, Goode brought to completion an arduous geo-and space science re-directional task first undertaken by Robert Lionel Sherlock (1875–1948) to reduce outdated geoscience's erroneous classroom teaching emphasis on over-emphasized Uniformitarianism. Humans, who even shove things upwards against gravity, are Earth's premier geomorphic agent: the voluminous published literature (Craghan, 2004; Wilkinson and McElroy, 2007) on mankind's movement of Earthly materials is, practically speaking, just about never-ending and is a "leading numerical indicator" measuring the notable influence of *Homo sapiens* on extant geological and biological process combinations (geophysical) directly related to ongoing Goodean "geoevolutionism". 1000 years ago, at least, our species began markedly to outstrip Nature's normal shifting of earthly surface materials; moderns have induced and triggered seismicity (Szabo et al., 2010; Acir and Ubeyli, 2010). More than half a century ago, famous biologists as, for example, Jakob von Uexkull (1864–1944), assumed a static view of Nature: the so-called "Balance of Nature" cannot occur, except as a continuum – i.e., as a temporary state of Nature. By 1958, Space Age scientists first fully recognized by global professional consensus the dangerous aerial build-up of anthropogenic CO_2 gas and the adverse affects on the remaining wildlife of human civilization's widespread artificial night-lighting.

Sidney Paige (1881–1968) suspected Earth's orogenesis and epeirogenesis was steadily, possibly solely, Sun energized (Paige, 1955); J. Marvin Herndon credits some of the remainder crust-change activating energy budget is completed by a smallish, erratic on/off pulsating center-of-planet-mass Earth fission nuclear "Georeactor" (Herndon, 2006). [Before circa 1946 in the USA, artificial "reactors" wherein nuclear chain-reactions occurred were then called nuclear "piles" because the reactor's shielding consisted of stacked compressed graphite bricks – essentially, an extension of ages-old wall and building construction technique after survivalist peoples imagined the housing and defensive architectural possibilities beyond the troglodytes' cave. As an aside remark, in the light of Herndon's subsequent published writings on decompression dynamics, it is my idiosyncratic persuasion that Herndon's theoretical "Georeactor" might best be termed a "Geo-Pile".] The physical stock and degradation velocity of Earth's mineral kingdom, viewed strictly as human resources is, more and more, being evaluated accurately and usefully (Capilla and Delgado, 2011). *Homo sapiens* exhume and inhume things on a vast geographical scale, including digging and burying artificial things such as surface landers and their associated supportive technical paraphernalia on the close-by Moon, Mars and Venus (Darrin and O'Leary, 2009; Capelotti, 2010)! Capilla and Delgado's compiled observations are statistical evidence-exhibits strongly reminiscent of S. R. Tobin's spectacular ceramic art! Industrial R&D uses modern investigational strategies (Rugescu, 2009) to design advanced infrastructure materials inspired, often, by changeable Nature; the goal, as always, is to make materials that prevent as much as possible the formation of cracks. Indeed, nowadays there seems to be a pervasive geo-philosophical contention that a radical break with past civilization trends is presently occurring, that the sum of all present-day social changes globally is sufficiently apocalyptic to serve possibly as an identifiable named post-Anthropocene Geological Time period. Since an epoch is the start of a new Geological Time period, the living are liable to have the distinctive opportunity to create delimiting, anthropogenic monuments on and inside this planet composed

of artificial stone! The built environments situated within Earth's biosphere are civilization's vital infrastructure, the footprint impression in Nature of all human activity, past and present; urban "metabolism" – all of the technical and social processes that take place in cities containing skyscrapers that results in expansion, energy production and sanitation/waste elimination (Kennedy et al., 2007); architects have proposed urban skyscrapers comprised of cast-concrete support members compleatly dedicated to agriculture – so-called "vertical farms" (Despommier, 2010); this ongoing effort seems to me to be a new, highly verticalized kind of pseudo-Nature overlay of an already vast unnatural geomorphic surface, in fact a kind of building mezzanine.

Anthropogenic rock strata, industrially installed during the 21st Century could become nameable geological dikes and sills, tilting or flat-lying man-caused igneous rock that cut across the bedding planes of the rocks intruded: for example, a potential aseptic "Stevenson's Stratum" formation subsequent to the creation, by a starting H-bomb explosion, of a self-propagating crack in the Earth-crust subsequently filled with 100 megatonnes of continuously-poured molten iron (Stevenson, 2003). In essence, Stevenson proposed an outrageously silly macro-project using an iron diapir situated at a new aerial nuclear explosive test site. However, as is often the case, he was not the first, merely the most notorious proposer of inner-Earth exploration technology since William Mansfield Adams (born 1932) had earlier offered a patented ("Nuclear Reactor Apparatus for Earth Penetration", US Patent 3 115 194, awarded 24 December 1963) self-sinking nuclear reactor designed to penetrate Earth's crust to a depth of ∼30 500 m that was to leave a near-vertical trail of solidified igneous rock (Anthropic Rock)! Both macro-projects were meant to return remotely-collected data from deep-Earth probes. Nevertheless, the creation of rocky dikes might, in the future, serve to support mankind's unsteady land-surface infrastructure by extending deeper a regular array of vertically excavated cylindrical holes in the Earth-crust that serve to markedly attenuate certain dangerous surface vibration frequencies during, for instance, major earthquakes (Meseguer et al., 1999). Man's most ancient stone monuments, the wonders of Greece and Egypt for example, might be shielded by such installations from destructive earth temblors (Tassios, 2010). And, on a much larger geographical scale, for instance, the Panama Canal, currently undergoing a costly expansion to permit more and larger ship traffic, is vulnerable to major earthquakes on two nearby faults (Rockwell et al., 2010). Such artificial dikes may even become identified as in many ways similar to keiroliths (fault rocks and mélanges) found, for instance, at Earth-crust subduction sites and fault offset zones (Sengor and Sakmc, 2001).

In his now proven 1963 theory of "chemiosmosis", Dennis Mitchell (1920–1992) fostered the concept that life is powered by a kind of "electricity" and that, possibly, Earth-life began inside rock (Orgel, 1999; Prebble and Weber, 2003; Bell, 2007). Yet, the majority of micro-organisms alive in Earth today remain undiscovered (Fierer et al., 2007). Natural and artificial rocks can be impregnated with inventoried known life[3]; it is possible with available biotechnology to "…create a conduit for electronic communication from living cells to inorganic materials…" (Jensen et al., 2010). After Mitchell, others – mainly brainy philosophers speaking to each other in communication-restrictive jargon – have gone so far as to "prove", by logical verbalized, mathematized and diagramed demonstration alone, that "…even inanimate matter must have some kind of mental aspect" (Bohm and Peat, 1987; Putnam, 1988; Ford, 2009). Hilary Whitehall Putnam, arguing in his complex theorem that every ordinary open system realizes every abstract finite automaton, together with the theory of computational sufficiency, implied that a rock has a mind! And, as well, certain insightful archaeologists allege and assert that, long ago, people invested natural stone with permanently housing human souls, that the deceased person resided in a particular natural basalt stele recovered at Zincirli in southeastern Turkey, when a hand-carved inscription so indicated. May we, then, imaginatively project into the remainder of the 21st Century, especially when Earth might be enclosed by a concrete roof carrying a glass cable communication system based on circum-Earth optic fibers (Meulenberg et al., 2010; Anker, 2005),whenever living organisms cease to be compelled to respond to the familiar geophysical daily, annual and lunar cycles (Foster and Roenneberg, 2008) and when, also, aerial carbon remediation efforts via direct removal of gaseous CO_2 and its long-term underground storage (Pielke, 2010), that "open-source" World Wide Web (Internet) planetary macro-engineering, emphasizing artificial stone creation, should come to prevail? Already, a genetically modified bacterium, *Bacillus subtillis*, is designed to knit cracked concrete structures: this industrial product, sold as "BacillaFilla" was first presented at the 2010 International Genetically Engineered Machine competition.

Currently, it is possible – almost an everyday occurrence in fact – for Mount Everest climbers to surf the World Wide Web, browse Twitter.com and post Facebook updates because, via a nearby base-of-peak 3G tower installation, even at the summit (consisting of Ordovician limestone, a cement ingredient) access to wireless Internet makes possible videophone calls (Skype) and texting (Evans-Cowley, 2010); at even higher altitude, since January 2010, the International Space Station has had Twitter.com service allowing Earth-gazing orbiting spationauts to send images from 362 km above the planetary surface. Our new-found ultra-Vitruvian Man ability to connect intellectually with individuals across planet Earth's surface and with planet-orbiting spacecraft at close to light speed has made the world we inhabit both "larger" and "smaller" simultaneously. Humans using smart

[3]See, for example, US Patent 5 948 474 issued 7 September 1999 to Norman Andrew Tiller and Louis George Grundel for "Bio-active Rock and Method for Making the Same".

cellular telephones, which contain distinctively specialized man-made ceramics with peculiar electronic properties, with appropriate applications, can monitor space weather created by the Sun and the cosmos impacting our planet (Tobiska et al., 2010). People, more and more prevalently, are imagining the future regional and global disruption of the organizational geophysical meld that is Nature and mankind by ill-applied "ingenious devices" (Clegg, 2010). With ~46 billion Earth-size planets virtually tallied in the Milky Way Galaxy, apparently there are many Aliens still to be contacted (Howard et al., 2010): probably, many extra-terrestrials, just like *Homo sapiens*, must also make artificial stone! This is one significant facet– universal application – of the categorical organization of unnatural rocks unanticipated by James Ross Underwood, Jr., or he was restricted from any topical discussion by unresponsive, possibly irresponsible, print journal editors (see Sect. 5).

During ancient times, the Greek's myth of the Gorgons involved three winged female monsters one of who had the power to convert people into stone merely with a single glance. (Sometimes, it almost seems, essay peer-reviewers and science journal editors have that ability!) In today's English parlance, "to gorgonize" a person is to metaphorically petrify someone with an intimidating glare. Present-day geoscientists are investigating the means to manufacture stone by the application of developing technology; some bold geoscientists, following the history of Anthropic Rock making, have not been intimidated by the near-term future mega-problem of providing a long-term macro-engineering rock-making technological fix (Cathcart, 1997; Bolonkin and Cathcart, 2009) to the anthropogenic Earth-atmosphere build-up of carbon dioxide gas evidently or apparently caused by worldwide industrialization and the aggregate exhaled breath of every living human (Fleming, 2010; Prairie and Duarte, 2007). Our functioning fossil fuel-combusting machines exhaust more CO_2 gas annually than Earth's respiring animals.

George Allan England (1877–1937), the science-fiction novelist, during 1906, postulated "The Lunar Advertising Co., Ltd" which would project from Earth somewhat collimated light-beams towards the Moon's near-side face to obtrusively sell commercially available products to the world's public and, during 1915, he penned "The Air Trust", a fiction espousing the idea of monopoly control of the world's air supply to economically exploit the prospect of human breathing privileges! It is breathtaking, or to say the least somewhat astounding, that printed language text should ever become a major part of humanity's commonly visible outdoor "landscape" via a floodlit Moon's near-side; literally, the Moon becomes a hemispherical texting screen! On a parochial note, on 27 February 2001, the US Supreme Court ruled in *Whitman v. American Trucking Associations (ATA*, 99-1257) that only human health factors can be considered in legislating and adjudicating ambient air quality standards. "Taken at its word, the Supreme Court ruling requires the US Environmental Protection Agency. . . to set air quality standards that are by definition too pristine to be in the public interest, and it requires the courts to make sure they do" (Ross, 2001). In other words, the United Nations Organization's collective managerial desire to limit CO_2 gas emissions, based, in part, upon the USA's Supreme Court judgment means that a "Sky Trust" might, someday, be organized that could set, and enforce, global limits on aerial carbon dioxide gas ejections into the global common (atmosphere) and the impingement of air-heating sunlight, directly from the Sun or, indirectly, from the Moon (Brunner, 2010).

Solidification of a large fraction of the Earth's existing aerial CO_2 has the potential to alleviate one facet, possibly caused exclusively by *Homo sapiens*, of looming global change – "anthropogenic global warming". Geosequestration of such artificial rock in the Earth-crust is being vigorously researched because CO_2 gas emissions to the air are, evidently, an immediate constraint on humanity's use of nuclear and fossil fuel-derived energy; stabilizing the Earth-atmosphere's CO_2 content will significantly affect energy use and the impact of climate on infrastructure and human life-styles. A gigatonne of carbon dioxide is $>1\,km^3$ as a liquid, reduced from $500\,km^3$ when an Earth-atmosphere gas. Here it might be informative for the reader to note that even the Moon's natural, formerly pristine, regolith surface-bounded exosphere has been augmented by our past and future mechanized exploration activities (Vondrak, 1974) – celestial body "climate change" in an initially lunar context. If the Moon's exosphere were 10 000 times denser, that satellite's atmosphere would become stable and not removable by the constantly impinging solar wind. In the recent past the Moon was once considered a likely nuclear and thermo-nuclear weapon/device test-site (Richelson, 2000). If ever conducted, such tests would have generated a greenish artificial stone called Trinitite, the material result of induced transformation as sand from the New Mexico desert was sucked upwards into the 16 July 1945 nuclear fireball and fell back in a dense precipitation of molten, quickly cooled glass (Parekh et al., 2006). Testing even peaceful nuclear explosives on the lunar regolith could obliterate Neil Armstrong's chronology-initiating sterile spacesuit boot footprints (Moore, 1980; Spennemann, 2004) as well as adding/removing gases from the Moon that were first unambiguously detected during the Apollo Missions – namely, ^{36}Ar, ^{40}Ar, He, Na and K (Fisher, 2010). When Armstrong's return vehicle, the Luna Excursion Module, blasted off the Moon to re-dock with the orbiting mother-craft, its rockets must have both eroded and melted some lunar regolith, making this deposit the first Anthropic Rock on the Moon's surface created in situ. If humans return to the Moon, and settle there "permanently", they will mine the regolith to create, say, photovoltaic cells housed in vast selenographical structural arrays (Raulin-Cerceau, 2010).

For the Earth-biosphere, man-caused carbonation reactions – i.e., the formation of solid carbonates – could occur during a dedicated industrial macro-engineering effort that would complement natural and genetically modified green plant photosynthesis (Jansson et al., 2010; Nibleus and Lundin, 2010). Of course, some gaseous carbon dioxide, in the form of concrete, has already resulted in anthropogenic geologic strata beneath civilization's urban regions (Kazuo, 2001; Alexandrovskaya and Alexandrovskiy, 2000), even poured rock pavements and roads; a specially concocted form of injectable concrete was used to permanently seal an early-21st Century Gulf of Mexico accidental oilrig blowout (Jernelov, 2010). The USA, after banned-by-international-treaty aerial nuclear weapon testing ceased at the Pacific Ocean site, capped some collected and bulldozer-piled nuclear waste deposits with thick, almost island-covering, concrete lids.

4 Range of familiar essential artificial rocks

Like some other animals, such as monkeys (Huffman et al., 2008), for millennia humans dug and piled only natural rocks (Turkington, 2005). During the 20th Century, however, archaeologists reliably first reported that ancient Mesopotamians had made synthetic basalt (Stone et al., 1998)! These items do not seem to have ever been used in the construction or reinforcement of cyclopean dams in that profoundly arid region, although it is possible, I tentatively suppose, that they simply have not yet been uncovered or recognized by archaeologists. Since then, as Czech geochemist Peter Jakes documented a decade ago, "there is a long history of cast-basalt production in Europe" (Jakes, 2001). The ancient Romans, of course, are justifiably famed for their widespread concrete use, even using it in their extensive, empire-wide system of laboriously prepared roadways and for submarine harbor foundations. Cast basalt (Kopecky and Voldan, 1965) in monumental dimensions continues to be a valuable factory-product and, nowadays, basalt continuous filament offered by "Sudaglass" Fiber Technology, Inc in Ukraine is used as an alternative to glass-fiber for concrete's reinforcement. Mineral wool insulation products made from comminuted rock/stone and slag wool became commercialized by about 1885 after their first use circa 1840 but the industry's growth happened mainly after "World War I. The extra-laboratory production of continuous glass filament commenced during the 1930s. Cement without reinforcement is at the present time an unsatisfying and weak building material. Victorians in the UK were intimately familiar with the durable mock-rock surface formations composed of manufactured "Pulhamite", invented by James Pulham (1820–1898), and "Coade Stone" in the public parks (Freestone, 1994). "Liquid Granite" Ltd., invented by the UK geoscientist Pal Mangat, and like "Pulhamite" and "Coade Stone" a secret formula for the composition of a low-carbon emissions concrete filler material, has come to the foreground during the early-21st Century. Synthetic rock hardscapes (e.g., Zen Gardens), contrived by cast stone artistry, became materialized "geo-illusions" in fact!

Apparently, since they are still enjoyed by strolling pedestrians, these artist-styled fake-rock public displays are extremely durable, perhaps equivalent in durability to rocky bio-generated structures (Krumbein, 2008) and various patented biocements (DeJong et al., 2006; Ivanov and Chu, 2008). Wolf Hilbertz (1938–2007) invented and trademarked "BioRock", assembled by applying a low-voltage, DC electricity to a metallic mesh immersed in seawater. Recently, it has been proposed that Venice, Italy, be safeguarded by seawalls brought into existence through the employment of a product akin to "BioRock" (Goreau, 2010); tested BioRock has ~3 times the load-bearing strength of ordinary (i.e., Portland) concrete. According to a Swedish architect, Magnus Larsson, microbial biocementation macro-projects may, in future, increase in geographical scale up to the mega-scale to stabilize some major sandy regions of northern Africa's Sahara dune landscape (Badescu and Cathcart, 2011). At the very least, roads might be stabilized in vast waterless sand dune regions. In an early-21st Century laboratory success achieved by Henk Jonkers in The Netherlands, which is inarguably reminiscent of Dennis Mitchell's "chemiosmosis", a bio-concrete was contrived to re-seal autonomously after bacteria and food were mixed – geochemical macro-engineering infection by intentional injection – into the raw test-site sand sample (Jonkers, 2007). The Netherlands' protective sea-dyke system could soon be markedly strengthened against possible future global ocean level rise by another outdoor test effort to install cultured bacteria; this technical development can only be regarded by bioscience, geo- and space scientist-historians as a complexification of Pietro Passerini's geographical-engineering concept of the "Anthropostrome" (Passerini, 1984). Biocementation is best described, perhaps, as a variant of anthropic metasomatism of the type forwarded theoretically by Roelof Dirk Schuiling (born 1932) under the banner of "geochemical macro-engineering" (Ravilious, 2004; Guinea et al., 2010; Schuiling, 2011). A science-fiction author, writing in a purely fictional manner and forum that is not too estranged from Schuiling's outlined scientific future reality, has proposed "slow sculpture": after millennia of natural chemical erosion, a sculpture emerges from a rock formation that was instigated by arduously-planned earlier anthropic chemical injection treatment (Mieville, 2005).

Ubiquitous bricks, formed by humans and automated factory machinery, have been omnipresent for several centuries (Holley, 2009) and, recently, archaeologists have devised examination techniques that permit accurate Geological Time-dating of fired clay ceramics like brick, tile and pottery (Wilson et al., 2009). In addition, French studies of bricks and mortar, done by Annick Chauvin, can now be processed in the laboratory to reveal the orientation of the Earth's

magnetic field at the time of manufacture. Magnetotactic bacteria (Haltia-Hovi et al., 2010) are clear indicators of Earth's past geomagnetic field-lines. Here, it must be noted, that a few macro-engineers as, for example, Bernard J. Eastland (1938–2007), have and are examining the technical and environmental aspects of advantageous modification of Earth's eponymous Van Allen radiation belts, discovered by James Van Allen (1914–2006) in 1958 (Rodger et al., 2006). It is widely postulated that Earth's geomagnetic field strength modulates surface air temperature (Usoskin, 2005), the solubility of gaseous carbon dioxide in standard seawater laboratory samples (Pazur and Winklhofer, 2008), the ocean's seawater currents (Ryskin, 2009) and measurable electromagnetic control of crustal seismic activity (Chelidze and Matcharashvili, 2003).

Bricks formed of concrete, instead of friable clay, can now be engineered with doubled durability via deliberate insertion of a patented nano-sized additive that causes slowing of the normal penetration of chloride and sulfate ions from applied snow-clearing road salt, seawater contact and adjacent salinized soils (Bentz et al., 2009; Lee et al., 2010). [Seawater-resistant iron rebar-reinforced concrete ships were built during both World War I and II (Nilson, 1980; Williams, 1992).] This is possible because the basic molecular structure of cement has, finally, become mostly understood by geo- and space science experts (Pellenq et al., 2009) after, possibly, nine millennia of *Homo sapiens* adaptation and use of all sorts of reinforced and non-reinforced cementations (Bentur, 2002). Obviously, in terms of nano-sized manipulability of materials, the complex behaviors of objects changes at a scale of ∼100 nanometers when forces not scoped to be in play in a major way at the macroscopic scale become predominantly evident at the microscopic scale and, thus, a true nano-engineering limitation on cement's adhesive-cohesive function probably exists (Schull et al., 2010; Sanchez and Sobolev, 2010).

Pavements (roads, sidewalks, etc.) contribute to Earth's global change (Santero and Horvath, 2009); pavements are composed of concrete and, of course, asphalt laced with reinforcing additions such as highly-comminuted, efficiently recycled concrete chips (Holley, 2003; Karnes, 2009). Intriguingly, James F. Black and Barry L. Tarmy (1963) proffered a coast-sited, rain-inducing macro-project for northern Africa that involved asphalted ground coating to increase local rainfall in that arid region. It was during his professional work life in Libya that James Ross Underwood Jr. (born 1927) first came to realize the importance of Anthropic Rock; being a keen observer, he was struck by the ubiquity of Roman cement "outcrops" present on Libya's beaches as well as inland from the coast. I think it was then, during his intensive fieldwork in Libya, that Underwood first fully realized, possibly in an "Ah, Ha!" or "Eureka!" moment, that *Homo sapiens* was no longer truly living on the Earth-surface, that our planet's outer limits had moved upwards to the top of the atmosphere and downwards to somewhere quite near the planetary crust's base. Subway planners and constructors, for instance, can create for the first time vast networked urban transportation systems with no geomorphologic relation to the space above the underground worksite. Perhaps it is not too much of a rhetorical stretch to state that humans, during 2011, remain Mother Earth's unborn fetus: "What is commonly called environmental consciousness could be described as subterranean – the awareness that we are in a very real sense not on the Earth but inside of it" (Williams, 1990). Perhaps the first somatic rocks were passed human gallstones!

The constancy of factory-fabricated rocks, including stackable and cementable glass blocks, featured in the many attempts undertaken, so far, to immobilize unwanted high-level radioactive wastes; the 20th Century geoscientist Alfred Edward Ringwood (1930–1992), a researcher in Australia, famously developed a titanate ceramic he named "SYNROC", an acronym for "synthetic rock" in which dangerously radiating nuclear wastes were to be lodged for storage for a vitally significant period of Geological Time (Bloomfield and Vurdubakis, 2005). [Whilst researching this essay, I found a hand-written note (to myself) informing that "synethetikites" – human-made rocks such as bricks, ceramics, concrete and slag – was coined by John Von Derlin. However, I can find no substantiating documentation to support that lodgment.] Chernobyl's New Safe Confinement structure, designed to encapsulate the Russian Federation's defunct nuclear fission Reactor #4 is, in part, composed of high-quality concrete to resist the long-term erosive effect of flowing freshwater present in a humid climate (Onishi et al., 2007). (Ignoring Sigmund Freud's advice that repressed instincts are dangerous to the human psyche, macro-engineers want to hide from public view all the ugly wastes humans discard.) The world's most-used building material, concrete, constantly under improvement in dedicated laboratories everywhere since the early-20th Century, has engendered and promoted some far-out ideas in the development of a multi-disciplinary study-field of Earth and planetary materials (Millward, 1979); in the same year of Millward's publication, for instance, the UK macro-engineering researcher David J. Sheppard announced low-Earth orbiting space-stations as well as hollow interplanetary and interstellar spaceships ought to be put together from standard unitized concrete segments (Sheppard, 1979); compartmentalized concrete spacecraft would be strongly resistant, generally unaffected, to the solar wind's known distinctly anti-biological effects (Harrop and Schulze-Makuch, 2010). Submarines, consisting in the main of ultra-strong concrete, have been built and tested for non-commercial and non-military applications (Cohen, 2002).

5 J. R. Underwood Jr.'s Anthropic Rock categories

Earth, as our species knows and loves it currently, has a closed-loop geologic cycle in which source rocks are eroded rapidly in the crust and continuously recycled by Nature and *Homo sapiens*. [This interpreted cycling is fashionably illustrated in a circa 1977 Disco Ball-era novelty educational comical cartoon, "The Crust-Ocean Factory" drawn and explained by Robert Minard Garrels (1916–1988) and F. T. MacKinzie (1971).] In contrast, the Moon evidently has an open-loop geologic cycle in which the rubbly crystalline crust is irreversibly pulverized by Nature alone. The most irrefutable geoscience evidence that Earth-crust rocks are recycled is an unconformity (Gregor, 1992); currently, Earth's non-contiguous seafloor deposits of sedimentary carbonate ($CaCO_3$) are undergoing slow dissolution, causing a non-depositional unconformity, not erosion deep-sea unconformity, and will probably continue to do so for >1000 years to come, because of the ocean's proved anthropogenic acidification (Berelson et al., 2007; Boudreau et al., 2010). Oceanic surface waters have already acidified by an average of ~0.1 pH unit from pre-Industrial Revolution state. Man-made things as, for example, concrete ship hulks resting on the seabed will also dissolve by the same destructive process if the existing oceanic circumstance is not ameliorated technically on a grand-scale (~70% of this planet's area)!

Leading up to the publication of his ideas on Anthropic Rocks in the 2001 papers, Underwood had presented the concept at two professional meetings in 1972 and 1976. A number of persons at the meetings and in later writing described examples of Anthropic Rocks that they had encountered in their professional activities. Earlier, Underwood had seen in Cappadocia (Turkey) the impressive dwellings and storehouse and warehouses as well as churches carved out of erosional pinnacles of volcanic rock, relatively soft beneath a harder weathered outer surface (Ulusay et al., 2006). In western Iran, high up on the massive Behistun Cliff, inscriptions in three ancient scripts describe Darius the Great receiving tribute from his conquered adversaries, provided the key to unraveling cuneiform, one of the old scripts. Most impressive of all, were the rocks in Petra (southern Jordan) where great massive monuments and facades have been carved and shaped in situ by the vanished Nabateans, early inhabitants of that frontier landscape site. To this day the exact purpose served by the different structures excised from the living rock is unknown. Later Underwood spent time teaching at universities in Iraq and Libya, countries in which ancient sites abound. It was especially thought-provoking that along the beaches of Libya, much of the coarser fraction of the beach material had not originated in Libya but had been transported there from the north shore of the Mediterranean Sea by Romans as they built seaside villas, temples, theaters, and baths. Wave action over the centuries since had destroyed many of them and much of the debris had been worked, re-worked, and rounded. Cobbles and pebbles of modern cement building blocks lay on the beaches, even though such material had been made and used there only for a decade or two. Underwood was struck by the thought that a sedimentological study of such beach materials would result in erroneous conclusions about the geological history of the region if the presence there of rocks made, modified, or moved by humans was not identified and considered in interpreting the history! The deposits he spied there might best be termed "anacrolithic" – literally, "rock out of time"!

In a Summer 2010 telephonic communication to me, the champion James Ross Underwood orally alleged: "My suggestion of several decades past of the addition of a fourth class of rocks to the long-established geological Holy Trinity of igneous, sedimentary, and metamorphic rocks might be as controversial as proposing to expand the Biblical Holy Trinity from three to four!" With unfailingly professional and certainly sagacious courage, however, Underwood proposed decades ago that the enormous quantity of brick, concrete, tile, cement, slag and glass produced each year by humans worldwide be designated collectively Anthropic Rocks and that they be considered a new class, joining the igneous, sedimentary and metamorphic rock classes. He further proposed that Anthropic Rocks be subdivided into three sub-classes: (1) anthropogenic rocks – those made by humans; (2) anthropotechnic rocks – those modified by humans, and (3) anthropokinetic rocks – those moved by humans.

Anthropogenic rocks differ from other rocks in several particulars since they are mostly formed by processes that can be observed and are well understood, the materials from which they are composed can be derived locally or can be brought from geographically distant resource extrication sites and their volume and rate of production are great. Once made, Anthropic Rocks can be used locally or moved great distances – even to higher elevations on land or deeper places beneath the geomorphic surface and the Earth's ocean and other bodies of water. Not to be overlooked are "Eternal Reefs" (www.eternalreefs.com), which are a mixture of a person's cremation ashes and concrete (typically a mixture of 60–70% sand and gravel or natural or unnatural crushed stone, 15–20% water, and 10–15% cement, which is prepared by roasting limestone, clay and other ingredients). Concrete has been used in sculpture since the 1920s and since the 1970s, with the advent of Land Art concrete is often utilized to function as a mortar to secure potentially shifting elements of such expressive outdoor artistic creations (Lin, 2006).

Concrete responds well to deep-ocean submergence: its inherent density makes it stable against sliding and overturning, it is durable in seawater and resistant to abrasion (such as erosion caused by moving bottom sediments) and in certain macro-engineered standard structural forms contemplated it has rigidity against buckling. Seawater hydrostatic pressure and low temperature (constant low seawater temperature and constant moisture availability minimize volume change and micro-cracking) and even enhance its basic

properties, resulting in increases in strength and modulus of elasticity! Moreover, all the engineering advantages (such as moldability) and economy are retained. Hence tremie concrete's use in high-seas submarine and ocean floor construction efforts during the 21st Century. Some anthropogenic rocks can be formed very quickly, even in milliseconds, by applied heating of existing materials (Mackedon, 2010) and some are emplaced in massively industrialized outpourings (Maurer and Yu, 2011).

Anthropotechnic rocks result from humans shaping, carving, or inscribing rocks of one of the four classes suggested by Underwood. The shaping or carving or inscribing can be accomplished on outcrops as at Petra in Jordan or on selected blocks of extricated rock – e.g., tombstones in cemeteries or on dedicatory cornerstones of buildings and other structures or on buildings. In the USA, during the 1950s, the National Institute of Standards and Technology built its extra-laboratory NIST Test Wall which is an aerial exposure testing structure to study the performance of stones subjected to outdoor weathering that are used by humans just about everywhere in building various facilities, installations and housing (Kessler and Anderson, 1951; Benison, 2005; Hyun and Park, 2011).

Anthropokinetic rocks are those of one of the four classes that have been extracted, removed and moved by humans – sometimes using machines and sometimes not – in energetic competition with Earth's omnipresent Nature from their place of technically accessible geological origin.

All broadminded and informed geo- and space scientists know that the living mentality to recognize a new (and perhaps not intoxicating) geological concept has probably always been a proxy for the commonly perceived *Zeitgeist* of the times. There are many who express the gift of leadership by sharing courageous ideas in compelling and inspiring ways. They demonstrate integrity, intelligence, creativity, enthusiasm and humility. Most persons learn from all such leaders, past and present, and they appreciate their insight and example.

Humanity's efforts to explore the knowable Universe from both the ground and outer space has created in the Earth-biosphere an infrastructural "stratigraphy of sorts" (Edmonds, 2010), sites for inquiring archaeologists and others to pick through with considerate care to discover scientific truth. Meantime, investigators are drilling into an expanding caldera situated directly below the Italian town of Pozzuoli, which has risen in elevation by 2.8 m since 1969, in their costly endeavor to acquire accurate data on any possible future hydrothermal explosion affecting that region; the Campi Flegrei Deep Drilling Project (CFDDP) was commenced because reliable information from surface studies is insufficient to provide any useful eruption warnings to the populace located near Naples. The CFDDP's bore is lined with indispensible concrete (Chipperfield, 2011), making the glass fiber-optic cabled instruments safe for continuous operation and vital real-time warning reportage.

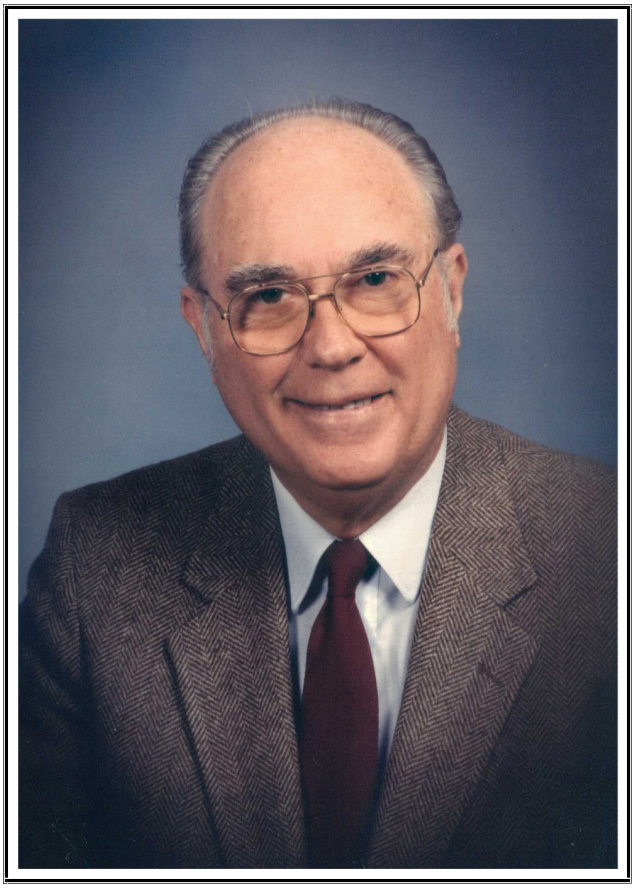

Figure 1. J. R. Underwood Jr., circa 1991. Credit: JRU.

James Ross Underwood Jr. (Fig. 1) struggled intellectually, literally for years, to outline a professionally suitable classification for all Anthropic Rocks; its basic premise of his published organization is that all rocks that have been made, transported, or shaped by *Homo sapiens* should be referred to as "Anthropic Rocks". The example descriptor provided – for a sedimentary rock that has been made, shaped, and transported by humans – would be in contrast to the descriptor for a conventional sedimentary rock that has been shaped and transported by humans: allo-, meta-, anthropic sedimentary rock. At first, during trial organization efforts, he had thought about reserving the term "anthropogenic" only for those rocks made by humans and using the term "anthropic" for those conventional rocks shaped and transported by people, differentiating between those by using prefixes "meta-" and "allo-". Still, he came to the over-arching conclusion that it would be well to refer to all rocks made by living and deceased persons with the all-inclusive umbrella term, "Anthropic Rocks".

Commencing circa 1972, he thoughtfully played with various combinations of prefixes and rock names: iganthropic, sedanthropic, metanthropic, anthroigneous, anthrosedimentary, anthrometamorphic. But, after a period of time elapsed,

he decided somewhat ridiculous complications would arise when the concepts of transportation and shaping by humans were added to the specialized, exceedingly unmemorable vocabulary. Lithification of Earthly materials is the key stage in the creation of Anthropic Rock and so, exactly a decade ago, he published his lithogenesis categories in a professional geoscience journal (Underwood, 2001a). Underwood deemed it necessary to do so because of the increasingly better known volumetric importance, and the pronounced unique genesis and characteristics, of Anthropic Rock. In other words, an additional class of rocks, anthropic or man-made, was proposed as a means of recognizing their ramifying abundance and significance.

Official recognition of Anthropic Rocks as a separate class results in several advantages for geoscience, space science and bioscience: (I) It brings an enhanced awareness and understanding of such unique Earthy materials; (II) It enhances verbal communication, whether written or spoken, and especially in the preparation of geologic maps and reports; (III) It enhances awareness of the role of *Homo sapiens* in modifying the Earth-crust and its changing mineral kingdom; (IV) It is a logical step in the same sense as was the first recognition of metamorphic rocks in the 19th Century as rocks that originated in ways and in places other than those of the rock classes then recognized (sedimentary and igneous); (V) It is applicable to other rocky, planetary and lunar-type surfaces with virtually no alteration or revision needed whatsoever. For more than thirty years, Underwood has consistently averred, in private conversations and in public pronouncements, that the concept of Anthropic Rocks is "... much more important than the terms" (Underwood, 2001b). This statement is borne out, if not satisfactorily substantiated, by the certain knowledge that *Homo sapiens*, yearly, emplaces intentionally ~4 km^3 of new concrete!

Advancement in geo- and space sciences can be conventional or unconventional: Underwood's additional "Anthropic Rock" categorical classification entry is not an outrageous suggestion voiced by a crank (Huggett, 2002) but, instead, an innovative provocation voiced by a considerate and emphatic man with, perhaps, a streak of professional persistence willfully exhibited in order to shift a seemingly common-sense rock cycling paradigm. The "Anthropic Rock" category is an intellectual conjunction, a turning-point in all future human understanding of the most important Solar System planet – our species' homeland. Although quietly mulled for at least three decades, the shown diagrammatical rock cycle diagram (Fig. 2) Underwood settled upon has the quality of abduction (also known as "informed guessing") that polymath and logician Charles Sanders Peirce (1839–1914) thought constituted a critical step in every geoscientifical inquiry; like Peirce, Underwood, apparently, exhibited the old Peircean proposal in the flesh, his mind naturally adapted to guess correctly!

According to geoscientist Victor R. Baker (2009), Peirce stated that the "... ultimate success of science depends upon

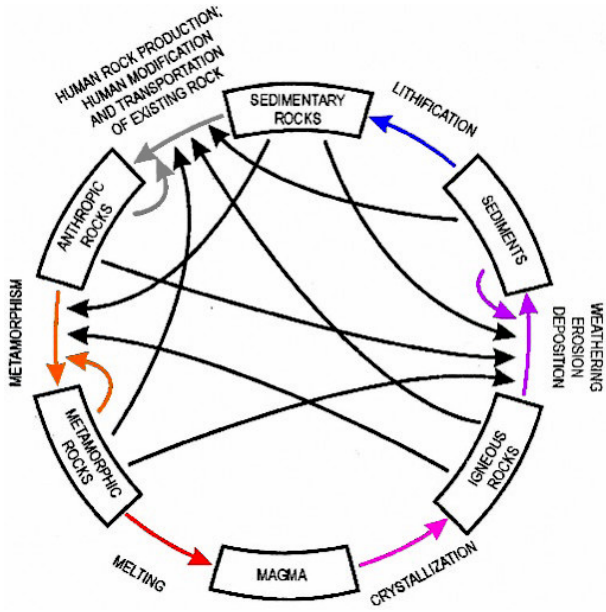

Figure 2. J. R. Underwood Jr.'s suggested impressionistic diagramming of the Earth's Rock Cycle, including Anthropic Rocks. Blocks represent materials, arrows represent processes. (Credit: JRU. Modified from L. Don Leet and Sheldon Judson, Physical Geology, NY, Prentice Hall, Inc., 1954:49. Diagram drafted by Michael L. Hackney and colorized by Joseph J. Friedlander).

an instinctive ability to reason to fruitful or productive hypotheses, that is, to guess right (formulate a correct abductive inference)". And, like the philosophers addressed in Sect. 2, the Peircean systematic triadic relation of signs provides a theory of metaphor – Peirce cautioned geoscientists not, by mistake, to conceive of the physical and the psychical aspects of matter as "two aspects absolutely distinct"; further, treading in the footsteps of Charles Babbage, he foresaw the future acceptability of computer-generated metaphors in geoscience (Peirce, 1887; Bruning and Lohmann, 1999). Thoughtful rocks are not at all an impossible reality! Unaffected by irrelevant emotionalized beliefs, which imply an irrelevant care and concern, J. R. Underwood Jr. conducted his "Anthropic Rock" geoscience investigation with an intrinsic practical approach to which C. S. Peirce might have given his unqualified thoughtful approval.

6 Predictive remarks

It is an obvious fact of our (so far) unfolded early-21st Century geo- and space science that most of Earth's carbon dioxide gas has already been converted to rock over the period of its existence as a planet in this Solar System. The standard geochemical model estimate is that if all the carbonate rock in our planet's crust were, somehow, baked out the following Earth-atmosphere would have ~60 bars of gaseous carbon dioxide; a simple calculation, which does not require a

proof shown herein, as to the average thickness of rock this represents is ~408 m. If, however, only the gaseous CO_2 in the present-day air were converted to Anthropic Rock, that global – and still to be named – stratum would, probably, be ~2.5 mm thick, or approximately a 1275 km cube of purely Anthropic Rock, each side of which is ~10.81 km. (That potential human-caused stratum could be only slightly thicker that the natural global iridium layer currently alleged to mark the boundary between the Cretaceous and Tertiary periods.) Anthropic removal of all carbon dioxide gas from air – it does not condense or precipitate naturally – would kill photosynthetic plants. Warming of Earth's atmosphere today, whatever the cause (Chaisson, 2008), could force the water vapor concentration to reach as much as 4%; however, if there were no vaporous water in the Earth's air, the temperature would decrease by 20–30 °C. Vaporous H_2O, instead of gaseous CO_2 could then become the main contributor to anthropogenic climate change; the absence of all aerial CO_2 would instigate emission of more water vapor radiation than would sustain global radiative balance[4] and cause the Earth's air to become cooler. In other words, according to informed hyper-environmental geoscientists, humanity will, someday, possibly cause the onset of a new Geological Time period for the Earth – the abruptly materialized Anthropocene/Nano-engineering Transition – characterized and typified in every superficial landscape, and the ocean's bottom, by the Anthropic Rock Class! The Anthropocene/Nano-engineering Transition must be taken to be a possible potential real-world as well as global human cultural event process (Williams et al., 2011). Already macro-engineers seek patented means to "provide world public with a safe and super speed planetary transportation system as an alternative to the slower and more hazardous present day systems of using ships and aircraft" (Friedmann, 2006). Humanity celebrates the superiority of our species' artifacts with cultural compliments that indicate mechanical perfection – a phrase such as some thing being as "smooth/clear as glass" is but one noteworthy Anthropic Rock example.

Worldwide use of the Fritz Haber (1868–1934)-Carl Bosch (1874–1940) process for fixing aerial nitrogen (N, discovered 1772), converting it to ammonia, then nitrate fertilizer for agriculture sparked humankind's first air-mining industry (Canfield et al., 2010). "If, via natural or artificial processes, it were possible to reduce the Earth's atmospheric pressure, the life span of the biosphere would be extended" (Li et al., 2009) – these researchers herald a future technology of macro-engineering which could drawdown drastically the common air's nitrogen content economically: however, concrete, its future spin-offs, synthetic diamond (Freitas, 2010) and transistorized non-plant leaf-centered electric power generation multiplied by the billions, enveloping intended regions of the planned and styled planet (Regalado, 2010), may become the rocky type-formation of choice for *Homo sapiens*. Removal of nitrogen from Earth's air could entail a determined packaging and shipment of all excess gas for exportation to Mars, where nitrogen is apparently absent, not so far a known component of any minerals observed there remotely.

As Henry George (1839–1997) recognized and characterized in 1879, Spaceship Earth/Gaia is a "well-provisioned ship…[moving] through space". And, one might add in 2011, it has walled compartments made of Anthropic Rock! In any future time of actual Mars terraforming by people, the Earth-biosphere will assume the role, perhaps, of a standing reserve owned by industrially productive *Homo sapiens*. The opposite of Sun-mining would be the exposure of planetary mantle-cores by crust excavation, thus causing the highly pressured and hot natural materials previously contained to become exposed to outer space, where such materials could cool gradually and, inevitably and eventually, form monumental Anthropic Rock masses of a calculable volume (Badescu and Cathcart, 2006). Such was the posited vision of the astrophysicist Fritz Zwicky (1889–1974) in his 1948 macro-engineering prediction of humanity's future total re-arrangement of all Solar System planets, including the breaking apart of our Solar System's gas giant planets. It seems quite fitting to end this non-chronological historical brief by thinking of a planet famous for its telescopically visible rocky rings (Saturn), especially considering the classificatory discussion of the Earth's rock cycle and the educated inclusion in it of a new category of rocks, the Anthropic Rock class as devised by the American geoscientist James Ross Underwood, Jr. during the ultra-exciting first decades of *Homo sapiens'* Space Age. Imagine humanity's possible Dyson Sphere – or, more precisely, a discontinuous "shell" of inhabited satellites, a structure larger than the Sun which virtually encloses our star for solar energy collection purposes – constructed by people and robots to harness almost all non-solar mass naturally orbiting our star: the result would be an artificial "Solar System" done, in part, with major input of recyclable Anthropic Rock (Arnold, 2005; Debiase, 2008; Carrigan, 2010)!

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Reviewed by: V. Badescu and R. Rugescu

Remarks from the Editors: History is more than just a chronological assemblage of events from the past, it is a guide for interpreting the present and for anticipating the future. In this spirit, and in light of conflicting referee reports, the Editors decided to publish this article in its entirety.

[4]The ultimate limitation on Earth-confined human solar-power use would become evident if it caused static air and a lifeless planet! Imagine the absence of romantic nights for-ever were Earth surrounded by orbiting mirrors reflecting sunlight onto our planet! L. C. Epstein, in Thinking Physics (2nd Edn., Insight Press, 1999:250), made this cogent point: "If the Sun's disc were smeared out (evenly) over the whole sky, the Earth's atmosphere would…not circulate at all".

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