Opening Statement

Around the world, but particularly in North America, organizations are attempting to sew doubt about basic, fundamental scientific realities such as evolution and the age of the earth with arguments that rely on distortions of the science (Coyne 2009; https://ncse.ngo/). The evidence for an ancient earth and the evolution of life is overwhelming and fully supported by the members of SEPM. We are a society of professional geologists in academia, industry, and government, specializing in sedimentary strata and paleontology, who have personally interrogated the evidence, publishing results, and moving the science forward. Our mission is "to create, share and disseminate sedimentary geology in the community" (https://www.sepm.org/About). Evolution and the ancient age of the earth are fundamental to our understanding of the world around us, and no young earth hypothesis can explain the basic observations of the rocks and fossils within them. Our investigations reveal that the evidence offered for a young earth is without merit and commonly based on false or misleading claims.

Below are summaries of some of the key lines of evidence that we rely on for understanding the ancient history of life on earth.

The fossil record supports evolution

Young Earth Creationists (YECs) commonly represent the Phanerozoic fossil record as a succession of communities that all lived at the same time, but are buried sequentially from deep marine to shallow marine, and finally terrestrial settings due to the rising floodwaters. However, this view is contradicted by the data. First is the clear evidence that terrestrial and marine fossil assemblages alternate in consecutive strata in much of the rock record, and do not preserve a record of increasingly terrestrial assemblages.

And even within the same fossil groups, there are successions of fossil species some of which are consistent over distances of thousands of miles. One example is the microscopic phytoplankton coccolithophores, which evolved in the Late Triassic, about 220 million years ago, and rose to global prominence during the Cretaceous. Successions of coccolith species have been well documented in the many deep sea cores, and the sequences of species are amazingly consistent over long distances, many occurring worldwide, and many species transitions are synchronous relative to paleomagnetic reversals and oxygen isotope cycles (Raffi et al. 2006). This is why coccoliths are among the most important biostratigraphic index fossils (De Vargas et al. 2007), are widely used by the petroleum industry, and are ignored by YECs. Consistent successions of planktonic microfossil species over long distances, independent of sediment type (mud vs sand vs limestone), contradicts a model in which the strata were deposited by a turbulent worldwide year-long flood. And finally, there are no coccoliths in Paleozoic strata, which, according to flood models, represents the most offshore marine communities where coccoliths are today abundant. They are absent because they had not yet evolved.

Horse evolution is well documented by a rich fossil record (Simpson 1951). The old view of a linear succession of fossil species in ancestor-descendent relationships has been replaced by a cladistic approach of a branching evolutionary tree. But the fossils still show a series of transitional states, in stratigraphic order, and the single modern genus *Equus* stands in marked contrast to a highly diverse adaptive radiation of the family Equidae over the last 55 million years. This fossil succession includes some three dozen extinct genera and a few hundred fossil species with distinct morphologies, and which range in size by almost two orders of magnitude (MacFadden 2005). There is also a wide range in dentition from short-crowned (brachydont) to intermediate (mesodont) and finally high-crowned (hypsodont) molars, which reflect changes in climate and diet, including frugivores (fruit eaters), browsers on soft, leafy vegetation in woodlands, and grazers in grasslands (Mihlbacher et al. 2011). All this variation in morphology, body size and dentition among horses (Equidae) is impossible to accommodate as variation within "the horse kind" (i.e., within one species) as argued by creationists and stands as unambiguous fossil evidence of evolution.

Hominids include humans, the great apes, and their common ancestor, whereas hominins include the African apes and humans. DNA sequences show that chimpanzees and human lineages diverged 5 to 6 million years ago (Shoshani et al. 1996). Many Miocene to Pleistocene ape and unequivocal hominin fossils have been recovered (Wood & Baker 2011). They are widely scattered in time and space and show evolution of different features at different rates (mosaic evolution). Phylogenetic relationships among hominin taxa are therefore disputed, but document a more-or-less unidirectional trend in cranial capacity from approximately 400 cubic cm some three million years ago to approximately 1500 cubic cm today (Jones et al. 1992). *Homo habilis* (2.1 to 1.5 Mya) is a missing link between the earlier hominin *Australopithecus* and the unequivocal members of the genus *Homo erectus*, which later gave rise to the Neanderthal and modern humans, a transition that is well supported by the stratigraphic appearance of fossils and by the application of cladistic methods (Wood & Baker 2011).

Radiometric dating works!

Geochronology is the scientific discipline of determining the amount of time that has passed since a geologic process occurred. The many geochronologic approaches, with their varied assumptions, are all consistent and indicate an ancient earth. It is possible for a single rock or sample to yield different ages from different analyses, but these each record a different geologic process. Some geochronologic ages coincide with the time that a rock or mineral formed, in some cases the measured age records a younger event, such as cooling through a particular temperature, passage of hydrothermal fluids, or even first exposure to sunlight. A set of geochronologic ages can track the evolution of an igneous rock from crystallization at high temperature, through cooling as the rock body rose upward through the crust, and eventually to exposure at the Earth's surface. Of relevance for this discussion, all of these processes yield ages that are younger than formation of the host rock -- none are "too old." Reliable interpretation of geochronology accordingly requires a full understanding of the physical, chemical, and biological processes that start a geochronologic clock ticking as well as application of a geochronometer that accurately records the passage of time.

The most widely applied geochronometric methods rely on radioactive decay to record the passage of time. Over 100 years of research in nuclear physics has shown that radioactive decay is a random (statistical) process whereby a radioactive parent isotope has a discrete probability of decaying to a daughter isotope in a given amount of time. This probability (or rate) of decay is determined by measuring the radioactive decay (e.g., with a Geiger counter) that occurs from a known amount of the parent material. Such experiments have been conducted repeatedly, by many different researchers, on all geologically useful decay systems, and are known with an uncertainty of 0.1% to several percent. There is no evidence to suggest that the processes or rates of decay have changed through geologic time.

There are two situations, however, in which radiometric dating yields ages which are "too old." First, is a rock in which some daughter isotopes were present in a mineral at the time of formation prior to the start of a radiometric clock; if these initial isotopes were not distinguished from the radiogenic isotopes, the calculated age would be significantly older than the true age. Fortunately, all the commonly used geochronologic methods are able to account for the presence of these initial daughter isotopes by measuring either the daughter/parent ratio of several different coexisting minerals (isochron method) or the abundance of other initial isotopes that did not result from radioactive decay. Second is a magma that includes crystals from a pre-existing rock. If these crystals do not melt, or have their geochronometer reset, the sample may yield an age which is significantly older than the host rock. Such complexities are recognized (and avoided) by careful imaging of the analyzed crystal (a new rim commonly grows over the older core) or by analyzing multiple crystals from a rock sample.

Many experiments have been conducted in which a rock is analyzed using several different radioactive decay systems which all yield the same crystallization age (within uncertainty) (e.g., Renne et al., 2013; Sageman et al., 2014). Given that each isotope system is measured using very different instruments and methods, and ages are calculated using decay rates that were determined in very different experiments,

the convergence of these chronometric methods provides high confidence that there are no systematic biases or inaccuracies in any of the commonly used geochronometers.

Other indicators of an ancient earth

Although radiometric dating provides the only quantitative method of dating deep geologic time, there are many other indicators of an ancient earth. Biologic reefs are living structures that grow up from the seafloor built by sedentary organisms bound to each other to form a rigid framework. They are not transported debris, but are preserved where they grew. Reefs were already present in the Precambrian, when they were mostly built by cyanobacteria. Phanerozoic strata record a history of successful reef builders with distinct body plans, each typifying certain geological periods, including, in stratigraphic order, archaeocyathids, stromatoporid sponges, and rugose, tabulate and scleractinian corals (Kiessling 2009), a succession that is common worldwide. Fossil reefs occur throughout the world and at many geologic strata, commonly hundreds of feet thick, and could not possibly have been formed in a single year-long flood.

Also, many strata of all ages contain within them preserved soils, or paleosols, that record deep weathering of the parent material on ancient landscapes. Paleosols include evidence of chemical, biological, and mechanical weathering, and have complex structures identical to modern soils. Some mature paleosols in the Jurassic Morrison Formation include deeply-weathered horizons, evidence of chemical leaching, and mature assemblages of insect burrows, and likely took thousands of years to form (Demko et al. 2004).

Economic implications

Everything we know about how petroleum is generated and accumulates indicates an ancient age of the earth. Data collected for petroleum exploration also indicates that the stratigraphic column originated as a result of a long and complicated history which is different in different sedimentary basins. Accumulation of organic-rich shales, which form the source rocks from which most petroleum originates, is incompatible with the rapid depositional rates and young ages demanded by YECs.

Also, many of the recent advances in our understanding of stratigraphy and interpretation of ancient depositional environments over the last half century are either made by petroleum geologists or funded by petroleum companies. Reconstructing past environments is a key element of modern petroleum exploration as a tool to understand the development of petroleum systems, and for prediction of petroleum exploration targets. YEC claims that understanding the evolution of the earth is not part of the petroleum business are not true.

Uniformitarianism

YECs consistently misunderstand uniformitarianism. The term first was coined in opposition to catastrophism to mean that Earth's history could be best interpreted as resulting from processes and rates operating today. This view has long been abandoned (Gould 1965), but is still cited by YECs to indicate a scientific world view intolerant of the flood model thus suggesting that their views and ours are equally biased. Today uniformitarianism means that physical laws are invariant in time and space. Interpretation of past events is based on applying a uniformitarian concept that can be used to constrain the set of conditions required to produce the features seen in the rocks, commonly to such precision that there can be no doubt of the depositional setting (e.g. river or beach, etc.). There is no *a priori* bias that conditions must mirror those existing today, and the evidence is overwhelming that a single flood cannot account for the features seen in the rocks. Examples of conditions interpreted from geology that are not consistent with conditions today include the catastrophic meteorite impact at the end of the Cretaceous (which was predicted to exist before it was found) and times in the past when the oceans were depleted in oxygen resulting in widespread burial of organic carbon.

Very few working geologists and paleontologists support a young earth

YECs exaggerate the number of working scientists in relevant fields who deny or seriously question evolution. In the Dissent from Darwinism (https://dissentfromdarwin.org/) list, 1,153 scientists signed the relatively weak statement:

> *We are skeptical of claims for the ability of random mutation and natural selection to account for the complexity of life. Careful examination of the evidence for Darwinian theory should be encouraged.*

The much stronger statement supporting a biblical account of creation (https://creation.com/creation-scientists was signed only by 195 scientists.

By comparison, Project Steve of the National Center for Science Education has a competing statement that reads in part:

> *Evolution is a vital, well-supported, unifying principle of the biological sciences, and the scientific evidence is overwhelmingly in favor of the idea that all living things share a common ancestry.*

This statement has 1,451 scientist signatories named Steve. In order to compare the lists of scientists who have signed the competing statements we need to consider only those who are named Steve (or Stephen, or Svein, etc.) and who:

accept evolution:	1,451	98.7 %
doubt Darwinian evolution	17	1.2 %
accept biblical creation	2	0.1 %

These proportions are consistent with our anecdotal experiences with colleagues. Or, in other words, a very tiny proportion of working scientists with advanced degrees in relevant fields seriously doubt evolution and the ancient age of the earth.

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