Rock of Ages

By Tom Mason, Director

It is interesting to note that the most quoted work claiming a young age for planet Earth is the work of Archbishop Ussher (1581-1656). In his Annals of the World (1650) he confidently dated the Earth as having been created on the evening preceding October 23rd 4004 BC; thus when he wrote he thought that the planet was 5654 years old. While this work is often derided for its naivety, at the time when Ussher wrote it was a record of considerable scholarship.

Ussher was the Archbishop of Armagh from 1625-1656, so it is has a nice symmetry that I should be writing this article in Armagh as a direct scientific descendant of the Archbishop. His work was consistent with the understanding of science in the 17th century when he was alive. My work is consistent with the benefit of over 350 years of further study and of a body of knowledge which allows for the better scientific understanding of the Earth's age in the 21st century.

> "Archbishop Ussher's work was consistent with 17th century science"

Any understanding needs to be founded on scientific observation and facts. Thus, in a stratified pile of sedimentary rock layers, the oldest are at always at the base, the youngest at the top, consistent with observations in lakes, rivers and oceans. Obviously this does not hold when the rocks have been contorted by Earth movements, folds, faults and suchlike. In such cases, other evidence is used to discern the top of the succession of rock layers.

Granite is a common igneous rock which comprises an interlocked mass of crystals of quartz, mica and feldspars. The common elements which form the crystals in granite include: silicon; potassium; oxygen; sodium; calcium; aluminium; iron and magnesium. The basic building block of all elements is the atom.

Image Credit: NASA

The Earth from space photographed by the crew of Apollo 17 in December 1972. Radioactive dating indicates that our planet is 4.55 billion years old.

Atoms have commonly been visualised (wrongly) as being like tiny Solar Systems made up of a central dense nucleus, comprising relatively heavy neutrons and protons. Together these give the atom its mass, or weight. This dense nucleus is surrounded by a cloud of fast moving electrically charged electrons, of little weight but with negative electrical charge. In stable atoms the number of electrons equals the number of protons, making an atom of neutral electrical charge.

Elements can also exist in different physical forms known as isotopes, where the atoms of the element can have slightly different numbers of neutrons in their structure, which makes isotopes of the same element vary in weight. The simplest example is the three natural isotopes of hydrogen, Protium, Deuterium, and Tritium. These are hydrogen atoms with 1 electron and 1 proton, 1 electron, 1 proton and 1 neutron, and 1 electron, 1 proton and two neutrons respectively. These extra neutrons give the deuterium and tritium isotopes greater mass than protium, the

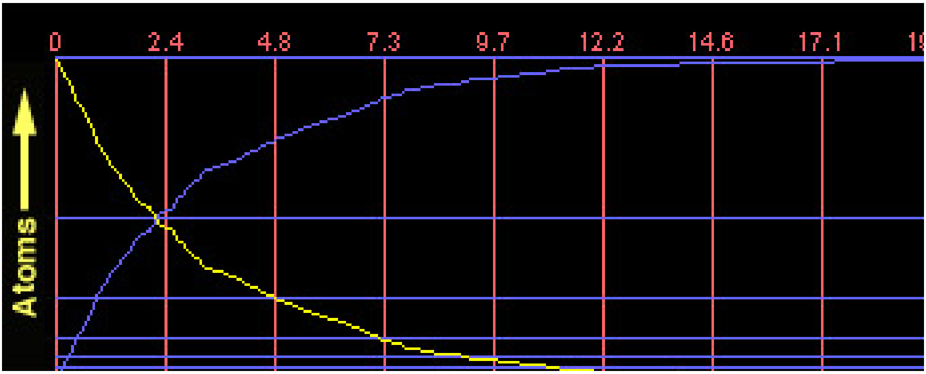


Image Credit: generated by www.colorado.edu radioactive decay site.

Radioactive decay The atoms in a sample of carbon 15 decay into atoms of nitrogen 15. This graph shows the number of C15 atoms (yellow) dropping as the number of N15 atoms (purple) increases as time passes. Can you estimate the half life of carbon 15 from this diagram?

commonest form of hydrogen.

Granites are defined as containing quartz, mica and feldspars, both of the latter minerals contain the light metallic element potassium (chemical symbol K). Potassium has 24 known isotopes, but for our discussion here we just need to be aware of three common ones. These are K39, K40, and K41. The commonest is K39 with just over 93% of potassium falling into this category, then there is K41 with around 6.7% and the rest (less than 0.02%) being K40. The natural isotope K40 is unstable and spontaneously changes into a more stable isotopic form (this is called radioactive decay) by losing beta particles or gaining electrons. This is a radioactive process, and is responsible for much of the background radiation which we humans experience.

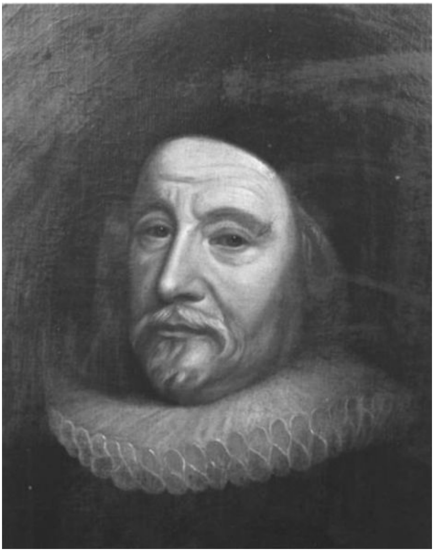
“...by carefully measuring the radioactive material in rock we could calculate its age”

A long time ago, it was realised that by precisely measuring the amount of radioactive material in rock samples, we could calculate the age of the mineral, and by carefully checking that the rocks had not been altered by subsequent events, this would allow a date to be given to the sample. To understand how this works, we need to understand the concept of half life. Each radioisotope has a constant half life: irrespective of how much of it exists in a sample. Thus, if we weigh a 10 gram radioisotope sample, with a half life of 20 seconds, after 20 seconds passes, only 5 grams of the radioisotope will be left. After another 20 seconds passes the sample’s weight will have halved again, and only 2.5 grams remain. This radioactive decay produces a very characteristic graph. The decay rate is constant and completely independent of all normal chemical and physical processes so it is a very predictable process. For a nice graphical demo of the 10C to 10B half life see: http://www.colorado.edu/physics/2000/isotopes/radioactive_decay3.html .

To date very old rocks the potassium 40 method is used. This isotope decays to Argon 40, but its half life is 1.3 billion years, for old rocks an alternative method is to use uranium 238 which has a half life of 4.5 billion years (obviously no one has observed a complete half life of this isotope, but it has been accurately determined by observing samples undergoing decay in the laboratory) . For comparison, plutonium 239, a very dangerous man made element, is found as a by product of nuclear bombs. Its half life is 240 000 years. This makes it a permanent pollutant for humans. Single tiny particles of plutonium inhaled or ingested are fatal.

This method does not work if rocks have been recrystallised by later events. So it is vital that

Image Credit: Artist unknown via wikimedia.org



James Ussher (1581– 1656) Anglican Archbishop of Armagh and Primate of All Ireland.

samples are fresh and unaltered. It works for samples from 4.6 billion years to around 100 000 years ago; this is based on the detection limits of the equipment used.

All of these techniques are standard scientific methods and refute the claims of Creationists that scientists are unsure of dates, and ages of ancient events are inconsistent. Scientists are trained to include their error bars in graphs and calculations as this allows others to compare and test their own results: error bars are not mistakes, they are good science. This is actually scientific rigour in action. Advances in dating techniques include more precise methods, and of course the different methods are calibrated and compared, and their internal consistency is very good.

There are many examples in the geological literature where rocks that were initially dated using fossil evidence have had their ages confirmed by radiometric methods. Initially dated by marine microfossils (of tiny organisms called foraminifera), the best example is the 65 million year old K-T boundary extinction event whose signature has been found worldwide. Dinosaur enthusiasts among our readers will be well aware that the K-T boundary marks the point in Earth's history when the 'terrible lizards' and many other species became extinct. Many glassy tektites (which are formed in meteorite impact events) found in well-defined sedimentary layers from different sites around the planet are dated at 64.5 ± 0.1 million years ago (Ma).

> "There are many examples where rocks dated using fossil evidence had their dates confirmed by radiometric methods"

Radiometric dating (Ar40 -Ar39) of melted rock samples from the Chicxulub crater in Yucatan where the fatal visitor from space fell provides a date of 65.07 ± 0.1 Ma (Swisher et al., 1992) which is close to two separate radiometric ages for the K-T boundary from the continental US: 65.00 ± 0.04 Ma and 65.4 ± 0.1 Ma (Gradstein et al., 1995: Obradovich, 1993). These are just examples. Independent researchers' results agree that the Earth is many times older than Archbishop Ussher's calculations. Although he would no doubt be greatly surprised by the correct value, as a man who delighted in truth and scholarship, the Archbishop would readily accept this new knowledge and envy us for our marvellous scientific tools.

References

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