Introduction to dating cave paintings

Figure 1: Predynastic Egyptian petroglyphs near the Kiosk of Qertassi (5 – 3,000BCE) New Kalabsha, Southern Egypt. Pat O'Brien

These animal carvings now in New Kalabsha, Southern Egypt are older than the ruin, the Kiosk of Qertassi that they stand beside (Figure 1).

- How do we analyse to find out if they are as old as we think they are?

The problem is that they are just marks cut or incised into the rock and our ability to age them is not as good as with organic materials. Defining the subject and age of rock paintings can mean archaeologists are able to determine more about the life of prehistoric peoples and acquire a better understanding of our origins. However, dating rock art has been a struggle for archaeologists ever since the first discoveries of it in the late 19th century.

It is possible to determine a number of things based on where the art is found and when it was found, but not everything can be learnt from that.

Dating ancient material relies on the use of two approaches – direct or absolute and indirect or relative dating or chronology.

For example, consider relative dating. If something is found with another object that the archaeologist already knows the age of and the area has not been disturbed since they were placed together, it is safe to say they both come from the same time. More importantly, if it is found below the object archaeologists know it must be older. That is called context or stratigraphic relationship and it's how archaeologists date objects as they dig. But it does not produce precise dates. If archaeologists can date something precisely that is absolute dating. The problem is it requires highly scientific methods.

There is a difficulty with something painted, particularly if the paints all seem to have the same composition. Here, archaeologists have to use the materials themselves and try to date it using some property or component within the material. The most common example of this form of absolute chronology, which we can use with rock paintings, is radiocarbon

dating. If we can use that technique it can give a reasonably accurate age up to approximately 50,000 BCE (Before Common Era similar to BC, Before Christ).

Radiocarbon dating

Radiocarbon dating (also called carbon dating) only works with organic things; materials that came from living things.

- Where does the radioactive carbon come from?
- How can it tell us how old an organic material is?

It relies upon the fact that plants take in carbon dioxide during photosynthesis and use it to make its chemicals. Animals eat these plants and the carbon is taken up into their chemicals.

The carbon element is composed of two different atoms called isotopes (meaning they have the same number of protons but there are differing numbers of neutrons in each different type of atom). When we add the number of protons, also known as the atomic number, to the number of neutrons, the total is the atomic mass number. The most common carbon atom has 6 protons and 6 neutrons, so the atomic number for this carbon isotope is 6 and the atomic mass number is 12. This can be written as:

$$^{12}_{6}C$$

Carbon typically has 6 neutrons making the isotope carbon 12 (C12), but some carbon atoms have 7 neutrons making carbon 13 (C13) and some carbon atoms have 8 neutrons making carbon 14 (C14). The carbon 14 isotope is radioactive. The various isotopes are found in organic materials in the proportions shown in Figure 2.

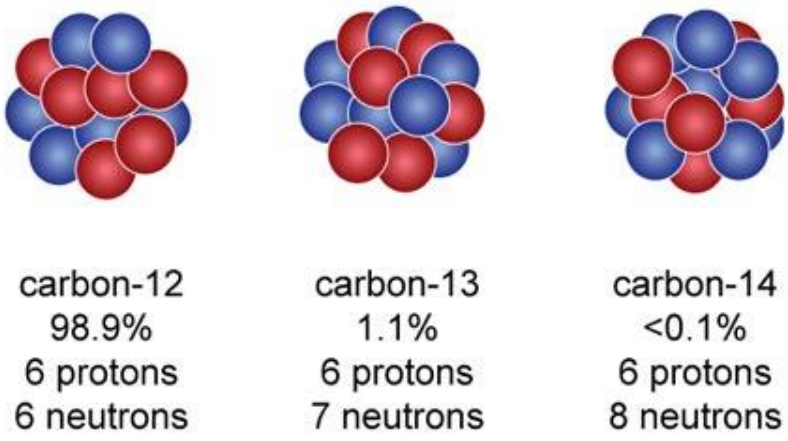

Figure 2: Carbon istopes (12, 13, 14). Peter Bull

All the time an organism is alive it takes up all forms of the carbon isotopes to make its chemicals but on death it stops taking in any carbon.

Carbon dating works because the amount of carbon 14 in the atmosphere has not changed in thousands of years. Carbon 14 is formed as cosmic rays hit atoms in the upper atmosphere. Living things, while they are still alive, absorb the isotopes of carbon. This means all living things have radioactive carbon 14 in them (Figure 3).

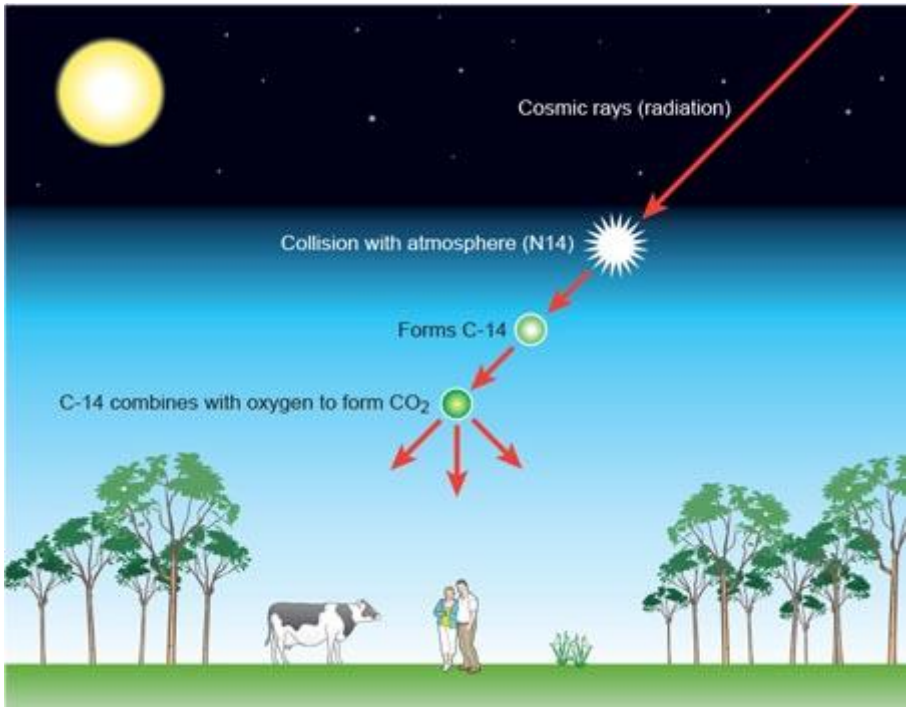

Figure 3: Carbon 14 entering the atmosphere. Image courtesy of Peter Bull.

After a living thing dies, the amount of carbon 14 in the material decreases with time it decays with a half-life of about 5700 years into nitrogen (Figure 4).

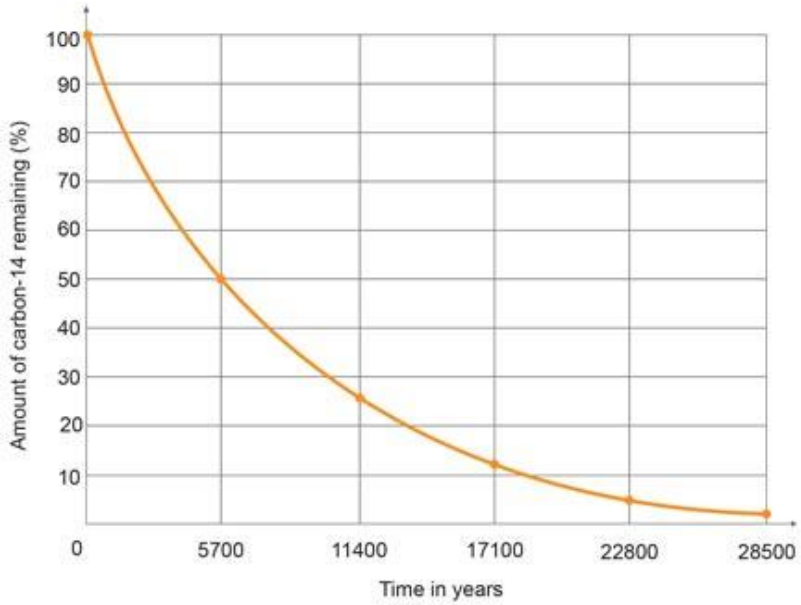

Figure 4: Half-life graph of carbon 14.

Carbon dating involves the measuring of the amount of the radioactive carbon isotope C14 absorbed by living things into the organic matter. By comparing how much carbon 14 there is in the dead organism with the amount in a living one, the age of the dead organism can be estimated.

Why can't we use radiocarbon dating with some pigments?

The difficulties with pigments

The difficulty with carbon dating pigments is that they are often made from rocks, and do not contain organic matter. Where there are engravings or paintings that lack any organic pigments or binders there is no basis for the build-up of natural carbon 14.

- What about limestone?
- Isn't that a sedimentary rock made up of once living cells and so contain carbon?

In some paints where suitable materials such as limestone, chalk or charcoal pigments do exist, we can use carbon dating. The sample size can only be very small otherwise the painting will be damaged or the level of contamination by the tools we use to take the sample will be high and could produce less accurate results.

Carbon dating also relies upon certain assumptions. The first is that carbon 14 has always been produced and had the same concentration in the atmosphere. This assumption is more important the older the carbon sample is. After 10,000 years there are no absolute calibration points such as tree rings. The second assumption is that radioactive decay rates stay the same and have always been what we measure them now to be. Because of the

half-life of carbon 14 the radiocarbon dating method is only useful for limestone's or chalks less than 30 million years old.

- Can radiocarbon dating be more accurate?

Up to 2009 only small amounts of organic matter could be dated directly using carbon isotope decay. Then a new, highly sensitive dating method, called accelerator mass spectrometry (AMS) was developed. It's an expensive but effective method, since it only requires 0.05 milligrams of carbon (the weight of 50 specks of dust). That's much less than the 1 to 10 grams of carbon needed with normal carbon dating.

In general terms, in AMS scientists create negative ions by bombarding atoms with fast moving particles which are accelerated using a particle accelerator. Then, using a mass spectrometer, they count all the carbon 14 atoms and from that work out the age.

To check its accuracy, research was carried out which analysed pictographs containing organic pigments from a number of countries over 15 years. This validation showed the method to be very successful allowing rock painting to join bones, pottery and other artefacts as materials that could be dated.

- Is radiocarbon dating the only absolute method for dating rock art?

Uranium-Series Disequilibrium

In 2010 a new development allowed the El Costillo paintings in Spain to be dated more accurately, pushing the advent of cave painting back 10,000 years.

This new method involved the measurement of the decay of inorganic materials. It measured the decay of uranium isotopes in the thin calcite flowstone growths that form on the surfaces of the paintings and engravings. Flowstones are created as water dissolves calcium compounds that are later deposited when the water collects on a prominent point forming a special type of stalagmite (Figure 5).

The research team was conducted by scientists from the University of Bristol. The team included Dr Paul Pettitt from the University of Sheffield's Department of Archaeology a renowned expert in cave art.

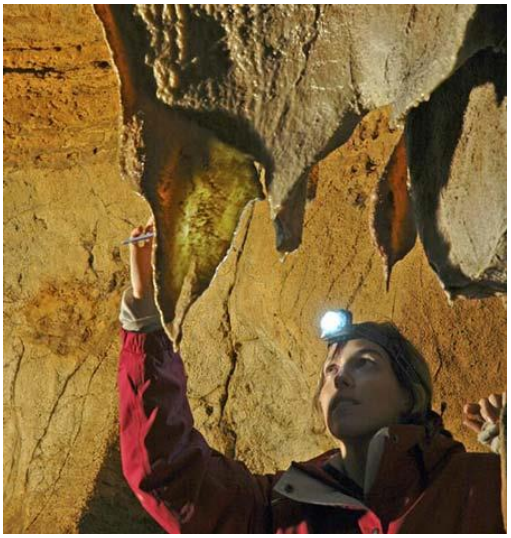

Figure 5: Scientist removing a sample from the surface of a flowstone in El Costillo. Tito Bustillo

Flowstones are formed where water flows down the walls or along the floors of a cave. They are typically formations in limestone "solution caves", where they are the most common secondary deposit or speleothem. Speleothem's can form in any type of cave where water enters, including igneous lava tubes. The water dissolves minerals, among which can be uranium isotopes.

The team of scientists from the UK, Spain and Portugal dated the formation of tiny stalactites on top of the paintings. This gave a minimum age for the art. Where larger stalagmites had been painted, maximum ages were also obtained. This technique is used a lot in Earth Sciences, and was used on 50 paintings in 11 caves in Northern Spain, including the UNESCO World Heritage sites of Altamira, El Castillo and Tito Bustillo. It is sensitive and avoids the problems in dating by radiocarbon.

Electron Spin Resonance (ESR)

Another method for dating calcite rocks is electron spin resonance (ESR) also known as electron paramagnetic resonance (EPR). This is based on the measurement of electron-hole centres accumulated with time in the crystal lattice of $CaCO_3$ exposed to natural radiations.

An electron hole is the absence of an electron from an otherwise full valence band. Imagine a row of people sitting in the last row in a theatre. The person in the middle gets up to leave and does this by jumping over the back of their seat into the next row and is then free to move away. The person is similar to a free electron escaping the atom and the empty seat is the hole. To even up the seating the people move along to fill the seat eventually leaving the hole at the edge so everyone has moved along. If the hole is assumed to be positively charged then the negatively charged electrons will have moved along leaving a positive hole

on the edge. This open electron shell or unpaired electron is known as a free radical and is highly reactive. Sadly ESR is not as reliable as scientists would hope so it is used with caution.

Many of these instrumental techniques are new to archaeological dating. In the past, in order to date cave and rock art, archaeologists looked for other methods such as those used by art historians. These are indirect tools often open to a lot of discussion as to their accuracy. They include the following:

Stratification techniques: The position of the object or painting relative to some other dateable objects. For example, in the cave of Le Tuc, France, two stalagmites had to be removed before the cave art could be reached and these were dated allowing an estimation of the age of the painting to be made.

Patination: The appearance of a film or scratches on the surface due to time. This has been used by some scholars to give a sense of the relative age of different petroglyphs. Sweinfurth, in 1912, was one of the first to use patination to date some engravings. Then in 1938 Winkler formed a chronology of archaeological occupation of the Eastern Desert. He based his approach on the strength of patination over the rock art scenes. He used a relative rating scheme to help him make estimations of age. A 0 rating was for a high patination and older, while a 10 was indication of a shallow patination and younger. Accepting Winkler's chronological scheme was innovative it has been attacked on many occasions because of the effect of the differentiation of light due to shade or weather due to wind direction on conditions over the surface of a rock painting, and how that might cause non-uniform patination.

Superimposition: Where one drawing has been etched on top of another. This could establish that one image is more recent than another, but doesn't give any information about the time gap between the drawings of the two images. Using a combination of superimposition and patination it might be possible to argue that the two are some distance apart in terms of age. However, there is always the possibility the artist superimposed one image over another deliberately, and that they are of identical or similar age.

Weathering: Where the impact of chemical and physical processes on an image after it has been created is determined. Lorblanchet in 1992 tried using radiocarbon dating to date some Australian rock art but found it inaccurate and so suggested that differential weathering could provide an indication of the relative ages of different rock art images. Unfortunately, weathering does not necessarily occur at a consistent rate across all rock art surfaces in a given area, and is not always a reliable way of determining relative ages. A more scientific approach to weathering is micro-erosion analysis, pioneered in Australia by Bednarik in 2002. One method is to examine the surface of a rock using a microscope and to measure the rate of weathering of the rock in a given area. This is done by sampling a number of rock surfaces set up to undergo simulated weathering and comparing the simulation with the actual weathering. In some cases the damage to rock crystals is used as the measure of weathering of the rock. A rock carved with petroglyphs is analysed in the light of this

accumulated data giving an estimation of the duration of time based upon manual erosion of the rock surface.

Style: Attributing a figure to a specific artist or group and evaluating the style of a painting to generate a relative timeline based on comparison of multiple works of art. A number of archaeologists have tried to create an artificial timeline for rock art using assessments of style similar to those applied by art historians. The difficulty is that what may be seen as art may have had, when they were drawn on the cave wall, a very different purpose a few thousand years ago. Academic perceptions largely depend on their own culture and history. This approach is very similar to seriation used by Sir William Flinders Petrie. He used relative dating of artefacts by the evolutionary change in their style eg moving from a simple rim to a ridged rim and straight sides to bulged side and then with handles, etc.

The method of dating art by style consists of grouping paintings on the basis of their stylistic components by selecting specific criteria that are the same or similar in a selection of pictures. The criteria are used to create an artificial set or “base sample” against which to compare other paintings

The chosen criteria can be details like the absence of paws, features like eyes or fur, the redoubling of certain strokes, or the blank spaces between two anatomical segments. Then when dateable paintings are found, their components can be matched with those in the stylist groups of paintings and a whole swathe of disparate paintings can be dated.

Alternatively extinct species are considered relevant. For example, the mammoth is a frequent topic of Upper Palaeolithic rock art and as the mammoth died out by the end of the last ice age, this provides a relative dating process.

The difficulty is that rock art is considered an art but is often analysed by archaeologists in a scientific way. For a number of years art historians have placed a high degree of reliance on the interpretation of the style of the painting and this approach has proven its analytical effectiveness many times in historical material culture. For that reason, rock art specialists try to apply this method to extremely old artefacts, like Palaeolithic art. Initial attempts by H. Breuil in 1952 aimed to establish a linear time frame for rock art.

Dating is still an area of development and criticism because of the imprecise nature of the material and methods available.