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# $^{14}C$ (Carbon) dating of cave and rock art

## Executive Summary

$^{14}C$ is a radioactive cosmogenic isotope which means it decays to half its atomic mass during a time span called a half-life. $^{14}C$ is called cosmogenic because it mostly forms in the atmosphere due to the interaction of the sun's rays with $^{14}N$. $^{14}C$ slowly decays back to $^{14}N$. The half-life of $^{14}C$ is 5730 years. Carbon in the atmosphere is dominantly present as $CO_2$. As we know $CO_2$ is a vital part of the earth's ecosystem. Plants use it via photosynthesis to grow. Animals in turn eat the plants, breathe, etc. Thus $^{14}C$ is present in every organism and as long as the organism lives, it will exchange $CO_2$ with the atmosphere keeping $^{14}C$ in equilibrium. However, on death, the exchange stops whereupon $^{14}C$ in the tissue decays with time. If we can predict the initial $^{14}C$ activity ($A_0$) when the organism died and it has remained in a closed system, then by measuring the present day activity of $^{14}C$ (A), the age of death (t) can be predicted with a simple exponential formula: $A = A_0 e^{-\lambda t}$ , where $\lambda$ is the decay constant for $^{14}C$.

Now it was initially thought that the activity of $^{14}C$ in the atmosphere has always been roughly equal to the present day assuming that the atmosphere is in a constant state of homogenisation. However, this turned out to be false. There are several factors that can change the activity of $^{14}C$ such as the sunspot cycle, Earth's magnetic field and atmospheric nuclear explosions.

Studies by Suess (1955) and de Vries (1958) of forests from the 17th century until the present day have shown that there is a variation in $^{14}C$ up to 2%. Because these variations are secular it was suggested that these are caused by the 11 year sunspot cycle. The sun builds up sunspots during 11 years and at the end of the 11th year the sun exhibits a burst of solar activity sending more than usual amounts of charged particles to the Earth. The theory was confirmed in 1965 by Stuiver using more detailed $^{14}C$ data.

The Earth's magnetic field is a shield that captures most of the harmful solar particles and sends them to the poles of the Earth where the effect can be seen as an aurora. This means that there will be more production of $^{14}C$ from $^{14}N$ at the poles. Studies have shown (Anderson and Libby, 1951) that the atmosphere quickly homogenises and that there is no visible variation in $^{14}C$ in today's woods. But through time the Earth's magnetic field fluctuates in strength and even reverses from time to time. Finally in 1967, with extensive paleo-magnetic intensity measurements, Bucha and Neustupny managed to model the effect of it on $^{14}C$ activity in the atmosphere. The result is shown in figure 1.

Lastly, it was proven that atmospheric atomic explosions increase the activity of $^{14}C$ in the atmosphere greatly. Luckily, because $^{14}C$ homogenises in the atmosphere quickly this has no consequences when calculating the age of a piece of organic material using $^{14}C$ dating method.

All in all, carbon can nowadays be dated in organic material up to a precision of 0.5% in a few minutes using a mg or less of carbon and is therefore a very reliable tool for dating. To do the measurements an expensive piece of equipment is needed to measure the $^{14}C$ activity of a small sample which isn't known to be older than 10,000 years. This is because after 10,000 years too much of the $^{14}C$ will have decayed back to

$^{14}N$ and would not be accurately measurable anymore. This equipment is called an Accelerator Mass Spectrometer (or AMS).

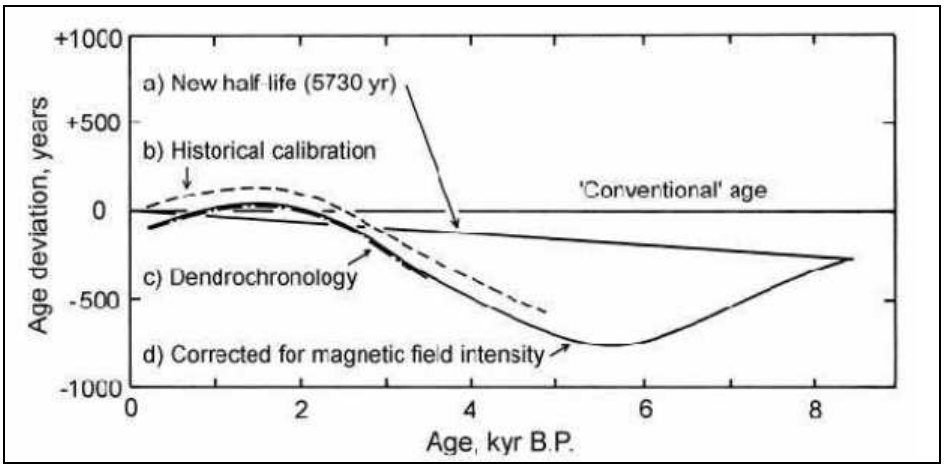


**Figure 1: Plot of age deviation between 'conventional' radiocarbon ages (half-life = 5568 yr) and other age determinations: a) radiocarbon method using 5730 yr half-life: b) historical time-scale; c) dendrochronology time-scale; d) using 5730 yr half-life and correction for variations in Earth's magnetic field intensity. After Bucha and Neustupny (1967).**

In this study my co-workers and I have need of this device to measure the $^{14}C$ activity in samples of charcoal coming from cave and rock art. The last decade has seen a sequence of increasingly spectacular finds of cave art, particularly in France, for instance, where the 1991 find of the Grotte Cosquer near Marseilles was followed in 1994 by the discovery of the Grotte Chauvet in the Ardeche. Prior to the advent of AMS, dating of such finds would have been forced to rely on stylistic interpretation and association with artefacts on the cave floor. AMS, however, allows the $^{14}C$ dating of the paintings themselves via the analysis of milligram amounts of charcoal, or other organic matter incorporated in the pigments, without significant damage to the art. Following the first successful demonstration in the French cave of Cougnac (Lorblanchet *et al* 1990), this method was employed in 1992 to date stylistically similar paintings of bison in caves at Niaud in France and at Altamira and El Castillo in Spain which ranged in age between 12.9 and 14 ka (Valladas *et al* 1992). Chauvet, which boasts 216 animals of remarkable stylistic sophistication, is older still at 31 ka, based on concordant dates from three separate paintings (Clottes *et al* 1995). These dates are the earliest ever obtained for prehistoric paintings. Since *homo sapiens* is known to have been present in the Middle East more than 90 ka ago, and since Grotte Chauvet indicates that sophisticated art was already being practiced 31 ka ago, these finds raise the expectation that even earlier sites may be found.

After the recent discovery of yet another, but even a more spectacular cave containing the most exquisite rock paintings ever seen, we believe that due to the artistic style, these paintings could possibly be the oldest yet found. To confirm our hypothesis we would need the use of the AMS. If we are indeed correct, then we will have unraveled another, but very important bit of the obscure history of mankind and its ancient lifestyle.