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Radiocarbon dating of twentieth century works of art

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Abstract The atmospheric tests of nuclear weapons caused a sudden increase in the radiocarbon concentration in the atmosphere from 1955, reaching its maximum value in 1963–1965. Once the nuclear tests in the atmosphere were halted, the ^{14}C concentration started to decrease. This behavior of the radiocarbon concentration is called the "Bomb Peak", and it has successfully been used as a tool for high-precision radiocarbon measurements, in forensic sciences and biology. In the art field, the possibility of dating canvas, wood and paper, widely used as supports for paintings, may be an invaluable tool in modern art studies.

1 Introduction

The principle of radiocarbon dating consists in the comparison between the ^{14}C content of the sample and the atmosphere concentration. The ^{14}C concentration in any living being is in equilibrium with that of the atmosphere during its life, due to metabolic exchanges. Following the death of the animal or plant, the radiocarbon concentration decays with the rate of the isotope, halving in 5730 years. This is the basis of radiocarbon dating of organic remains of archaeological interest: the measurement of the isotopic fraction $^{14}C/^{12}C$ in a biological remnant gives the time elapsed from the end of its life.

The nuclear tests in the atmosphere resulted in the doubling of the atmospheric concentration of ^{14}C (Fig. 1), which reached its peak in the northern hemisphere in 1963 [1]. Such tests were banned in 1963, as a consequence of the signing of the Partial Test Ban Treaty.

The "Bomb Peak" has allowed dating of recent documents in forensic sciences [2, 3]. In the art field, this paper shows that it can be used to date organic materials used as supports for works of art from the second half of twentieth century and may be an effective tool for authentication, capable of identifying forgeries made after 1955 of artworks purported to have been made prior to that date.

2 A twentieth century forgery

A painting bearing a signature of Fernand Léger, and purported to date from 1913 (Fig. 2), is conserved in the repository of the Peggy Guggenheim Collection (PGC) in Venice, as its authenticity had been questioned by some art historians. Radiocarbon dating was performed on a sample of excess unpainted canvas, part of a tacking edge folded on the painting's reverse.

The response of the radiocarbon measurement, performed by Accelerator Mass Spectrometry (AMS) at INFN-LABEC (Laboratorio di tecniche nucleari per l'Ambiente e i Beni Culturali) in Florence, was conclusive: The level of detected concentration was inconsistent with

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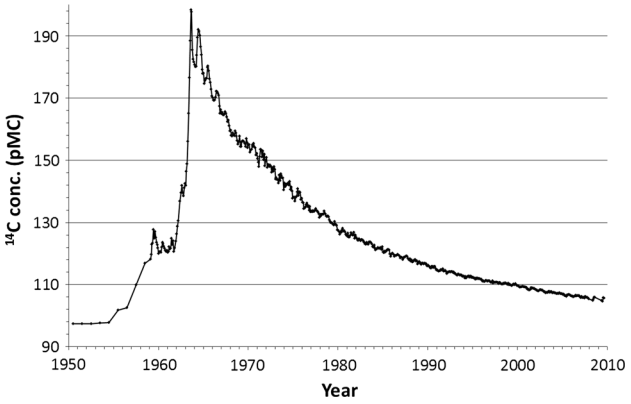


Fig. 1 Radiocarbon concentration in the atmosphere since 1950. Data are reproduced from [1]. The concentration is expressed in "percent of Modern Carbon" (pMC), setting to 100 the ^{14}C concentration in the fifties

Fig. 2 After F. Léger, *Contrastes de formes* oil on canvas, 92 × 74 cm. Venice, Peggy Guggenheim Collection (Solomon R. Guggenheim Foundation)

the period of the artist's life. The cotton of the canvas, indeed, was found to have a radiocarbon concentration only consistent with a plant still alive in 1959, i.e., after the death of Léger in 1955 [4].

3 Dating canvas

Dating of canvases used as supports of paintings of the second half of the twentieth century may be one of the most obvious applications of this method.

Since many such paintings still have their tacking edges folded around the backs of their stretchers, the necessary sample, which is destroyed in the analysis, can be removed without damage to the artwork. Moreover, thanks to the sensitivity of AMS, the withdrawn material can be reduced to a few milligrams: in practice a few yarns of a few tens of millimeters of canvas.

However, the dating of canvases is not necessarily straightforward. In the course of the twentieth century, artificial and synthetic fibers such as rayon and nylon, produced from hydrocarbons, were often mixed with natural fibers. Hydrocarbons, derived from organic compounds formed millions of years ago, no longer contain radioactive carbon, so that the measured concentration leads to incorrectly ancient dates.

The synthetic fibers can be quite easily recognized and distinguished from natural ones by optical or electronic microscopy. Thus, each time a canvas sample is examined for dating, a good practice is first to check whether the origin of the fibers is natural or not, in order, eventually, to date only the natural ones.

Figure 3 shows measurements of radiocarbon concentrations obtained on natural cotton canvases, labeled by the date painted on the artwork.

This date is clearly subsequent to the year of the "death" of the cotton plant of which the canvas is made. We may notice that there is a lapse of some years, from 2 up to 10, between the date inscribed on the artwork and the measured one: This corresponds to a delayed use of the canvas.

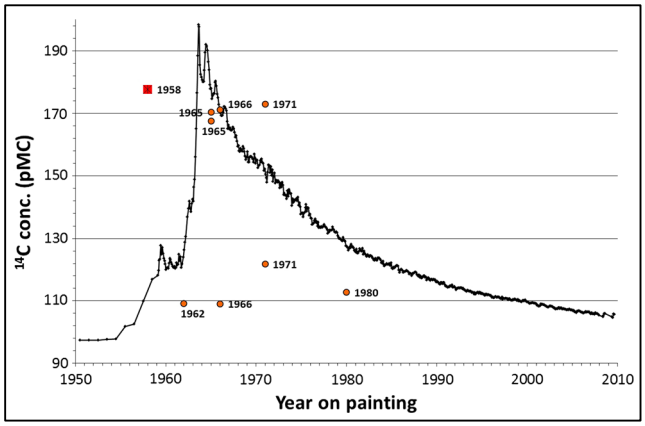
The only exception is the painting indicated by the red square. The date on it claims that it was painted 5 years before the production of its canvas. This anachronism signals a possible counterfeit and indicates the need for further investigation.

4 Dating wood

Wood has been used in the art of the twentieth century, and still is, to create sculptures as well as stretchers for paintings. Examining here the possibility of radiocarbon dating of contemporary artworks, we cannot disregard the difficulties that this material poses.

A common problem in the radiocarbon dating of wooden artworks, not necessarily of the twentieth century, is encountered when consolidation has been performed with acrylic resins (e.g., Paraloid B76) that contain no radiocarbon. In this case, a significant backdating is obtained, due to the contamination of the consolidant.

Contamination must first be removed, and the general interest in this regard is feeding studies at various laboratories.



Sample code	Year on painting	^{14}C conc. (pMC)	Calendar age (AD)
EA2/58	1958	177.60 ± 0.50	1963 or 1965
Can1962	1962	109.19 ± 0.76	1956-1957
Can1965	1965	167.55 ± 2.18	1965-1966
EA1/65	1965	170.30 ± 0.74	1963 or 1965-66
Can1966B	1966	109.09 ± 0.38	1956-1957
Can1966N	1966	171.1 ± 1.09	1965-1966
Can1971A	1971	172.98 ± 0.55	1965-1966
Can1971C	1971	121.83 ± 0.80	1959-1962
Can1980	1980	112.76 ± 0.64	1957-1958

Fig. 3 Radiocarbon concentrations measured on nine dated canvas paintings of the Bomb Peak period. The year painted on the canvas, the measured radiocarbon concentration and the corresponding calibrated age, at 95% confidence level, are reported. Due to the shape of the peak and to fluctuations, two or more calendar periods are given. Here, the most recent one has been dropped since it conflicted with other documented evidence, such as the presence of the painting in a public collection

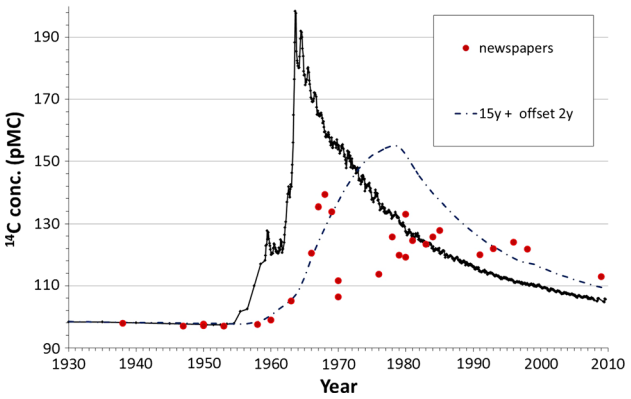


Fig. 4 Radiocarbon determinations on 28 daily newspapers, published in Italy from 1938 to 2009. The dashed curve plots the moving average of radiocarbon concentration in atmosphere over 15 years, delayed of 2 years

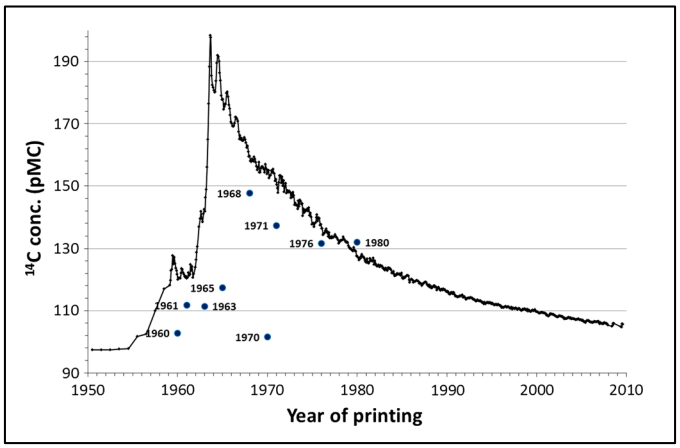
Currently, the sample pre-treatment with chloroform, tested at the LABEC in Florence [5], looks promising.

5 Dating paper

The radiocarbon concentration of newspaper samples (Fig. 4) shows significantly lower values than those detected in the Bomb Peak, because this is low-quality paper obtained from trees specially grown for periods from 15 to 30 years.

The radiocarbon concentrations are then averaged over such periods, and the relevant fluctuations are in part due to the different collection intervals [6].

The situation is different for drawing papers, from linen or cotton plants, with annual harvest. In this case (Fig. 5), the $^{14}C/^{12}C$ ratio is typical of the year of plant life and the



Sample name	Printing year	^{14}C conc. (pMC)	Calibrated age (AD)
Carma60	1960	102.80 ± 0.63	1954-1956
Abe61	1961	111.75 ± 0.79	1957-1958 or 1993-2000
Far63	1963	111.45 ± 0.68	1957 or 1993-1999
Seve65	1965	117.41 ± 0.82	1958-1959 or 1986-1990
Cobra68	1968	147.66 ± 0.80	1962-1963 or 1970-1973
Mac70	1970	101.60 ± 0.59	1953-1956
Moore71	1971	137.29 ± 0.98	1962 or 1974-1977
Candi76	1976	131.69 ± 0.36	1962 or 1977-1979
Papa80	1980	132.01 ± 0.63	1961-1962 or 1977-1979

Fig. 5 Radiocarbon concentrations measured on nine samples of fine paper for art and drawing, manufactured in the Bomb Peak period. The year of printing, the measured radiocarbon concentration and the corresponding calibrated age, at 95% confidence level, are reported

measurements are directly related, although not necessarily coincident, to the year of production.

6 Conclusions

Radiocarbon dating of twentieth century paintings with the Bomb Peak is an innovation for the contemporary art field, being the only absolute dating method for works from 1955 to the present. It has obvious authentication applications and may also contribute to chronological studies of artistic *oeuvres*.

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