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BOMB ^{14}C ON PAPER AND DETECTION OF THE FORGED PAINTINGS OF T'ANG HAYWEN

Irka Hajdas[1]* • Philippe Koutouzis[2] • Kate Tai[2] • Laura Hendriks[1] • Mantana Maurer[1] • Maria Belen Röttig[1]

[1]Laboratory of Ion Beam Physics, ETH Zurich, Otto-Stern-Weg 5, 8093 Zurich, Switzerland
[2]T'ang Haywen Archives 曾海文檔案庫, 28 Bonham Strand, Sheung Wan, Hong Kong, SAR, China

ABSTRACT. The bomb-peak signal preserved in the Arches® cotton paper was used to detect art forgeries imitating the work of Chinese artist T'ang Haywen (1927–1991). The dating of seven legitimate T'ang Haywen art pieces showed that the timing of the paper production was consistent with the artist's use of Arches® paper starting in the early 1980s. The measured $F^{14}C$ of the paper from the 14 suspected forged paintings shows that the support material was produced in the last decade (2008–2011), therefore the art pieces could not be genuine T'ang Haywen works.

KEYWORDS: art, bomb peak ^{14}C, forgeries, paper.

INTRODUCTION

The developments of the WWII nuclear program (Manhattan project) and the following decades of nuclear tests left a mark on the environment by releasing numerous artificially produced radionuclides (Hancock et al. 2014; Waters et al. 2015). Following the tests of thermonuclear weapons, among others, an excess of radiocarbon (^{14}C) was produced in the atmosphere, which strongly disturbed the natural steady-state concentration of ^{14}C in the atmosphere.

This very dramatic increase, nearly doubling the atmospheric ^{14}C content, began with the first weapons tests in 1953–1954 and continued until 1963 when the last tests were conducted shortly before the Partial Test Ban Treaty was signed in 1963 (Nydal and Lövseth 1983). This fast rise and slow decrease became known as the "bomb peak" and was transferred to the other reservoirs of global carbon due to natural intermixing exchange (biosphere, ocean, sediments, and soils). As soon as the first observations of the rising atmospheric concentrations were made, radiocarbon researchers began monitoring the atmospheric ^{14}C content (Rafter and Fergusson 1957; De Vries 1958). The data sets, which are continuously updated (Hua et al. 2013; Levin et al. 2013), are available in calibration software (OxCal, CaliBomb) allowing a comparison of measured values with the experimental data collected around the globe (Reimer et al. 2004). These are compiled into 5 zones, which reflect the differences observed between the hemispheres as well as equatorial regions (Hua and Barbetti 2007). Therefore, for all radiocarbon analysis, the source of the material, i.e., its geographic origin, is of importance. Moreover, the application of the bomb peak ^{14}C will soon be limited to the years 1954–2020, as the bomb peak atmospheric ^{14}C levels are diminishing due to the Suess effect (i.e., combustion of fossil fuel) as discussed by Graven (2015).

The history of paper is fascinating and sufficiently long (> 2 ka) to provide objects for radiocarbon research. Paper was invented independently in Asia (China; see Hunter 1978 and Needham 1994) and precolonial Mesoamerica (Binnqüist et al. 2012). On both sides of the world, paper was considered to be a most valuable commodity and was therefore preserved and protected. Some of those precious objects survived and were discovered in the course of geographic expeditions and colonizations (Nicholas 2013). Even though the preindustrial paper is an excellent material for ^{14}C dating, as it is produced from a short-

*Corresponding author. Email: hajdas@phys.ethz.ch.

lived material, analyses of historical objects are rare, because ^{14}C analysis is viewed as destructive. Presently, however, a few milligrams of paper can be used for measurements, which might allow most valuable documents to be sampled; see for example Hendriks et al. (2016).

Analysis of modern art has more acceptance for ^{14}C sampling as the bomb peak can provide compelling evidence regarding the possible attribution of an artwork (Caforio et al. 2014). Moreover, contrary to historical objects, the question of authenticity of the studied objects is clearly formulated. In the case of 19th–20th century paper objects, the main issue in radiocarbon dating becomes the source of the carbon, which in fact, is related to the source of cellulose. Before 1845, i.e., prior to the patent by Friedrich Gottlob Keller, which described how paper pulp was produced from wood, paper used to be made from old rags and a mixture of other short-lived materials (Nicholas 2013). Such a carbon source should have a non or negligible age when used for papermaking. However, wood as a source of cellulose in the paper pulp can be of mixed sources (recycled wood, mixed fragments of trees that could significantly differ in age) and consequently this material is bound to carry a mixed ^{14}C signal, as was demonstrated by a study of newspaper paper and drawing papers conducted by Fedi et al. (2013).

Additionally, the process of recycling can also change the ^{14}C content of paper. Paper remaking was already practiced in the 11th century in China and later in the 16th century in Japan where old manuscripts from the Imperial Library were sacrificed to make new sheets of paper (Hunter 1978). It remains to be clarified to what extent such "recycling" affects the age of preindustrial paper. The impressive variety of wood and non-wood papers combined with their various applications such as art, decoration, money (for example U.S. dollars), historic or legal documents demonstrates a need for a successful ^{14}C determination on paper independent of the source of pulp or the time period when it was produced.

Thus, research on the paper structure and the history of the specific paper production and use is crucial to an understanding of the measured ^{14}C ages. Moreover, pilot studies (Huels et al. 2017) showed that even wood-pulp-based paper could be successfully radiocarbon dated by selection of starch, which is an essential component in the papermaking process (Maurer 2009). Paper contains ca. 8% of starch, which carries a ^{14}C signal acquired in a short growing season of potatoes or corn, waxy maize, wheat, or tapioca. The unique signal of the bomb-peak ^{14}C described above carries a high potential for the detection of forgeries but also for dating the pieces of work created during the last 60 years. When applied to the right material the stories it reveals are often surprising and compelling.

In this paper, we present an example of a study that was designed to detect forgeries of paintings made on cotton paper and attributed to Chinese painter T'ang Haywen. Our study focuses on material that has been surfacing on the art market with claims that T'ang Haywen created it. Suspicion regarding these artworks' authenticity was raised following incoherencies in the aesthetic appearance, style of the painting, pigments used, or the signatures, which are subjective opinions. Radiocarbon analysis, on the contrary, is unbiased by personal judgement and offers indisputable evidence regarding their attribution to T'ang Haywen. The development of T'ang Haywen's use of painting material and specifically of the support is of major significance for the identification of counterfeits by ^{14}C dating.

Here we analyze pieces that were created on Arches® paper, which is a cotton paper produced for artistic use. The time when T'ang Haywen used that support material, i.e., from 1983 to 1984 until his death in 1991, is clearly in the range of the bomb peak curve, therefore, has a potential for a clear answer.

Painter T'ang Haywen (1927–1991) and His Legacy

The artist T'ang Haywen was born in Xiamen, China, as Zeng Tianfu but when he was 10 his family moved to Vietnam and lived in Cholon, the Chinese quarter of Saigon (presently Ho Chi Minh City). After WWII, in 1948 he left for France to study medicine but instead attended an art course at the Académie de la Grande Chaumière. His work indicated a Chinese spirit, as his intellectual development was influenced by his grandfather's instructions in calligraphy and the principles of Taoism.

In his early works, T'ang Haywen explored a variety of themes: Paris landscapes, interiors, portraits, self-portraits, and still-life. Then in the 1960s, he developed a preference for gouache, watercolors, and ink on paper. These paintings were realized on cardboard sheets of standard dimensions. Initially, he used the formats 29.7×21 cm and 70×50 cm, then two sheets of 29.7×21 cm side by side to form a diptych of 29.7×42 cm. Finally, he refined his approach and invented the space of the large diptych of 70×100 cm that characterizes his work.

He signed his works as TANG in capital letters then changed from TANG to T'ang with an apostrophe. His most frequently used signature, associating Roman letters and Chinese characters, became T'ang 海文 (where the characters 海文 are his surname Hay-wen).

Relevant to this study and ^{14}C dating is the fact that at the beginning of the 1980s, T'ang Haywen continued to paint diptychs in various formats, small triptychs in ink and color as well as numerous small watercolors that his friends would use as greeting cards. The large diptychs, which were exhibited in Brittany (France) at the Musée des Beaux-Arts de Quimper and at the Musée du Château de Vitré in years 1983 and 1984, were still painted on cardboard (possibly wood pulp or recycled). However, following that exhibition, T'ang Haywen began to paint on high-quality art paper of Arches®. Such a change in material is an important turning point as this paper is made of cotton therefore ideal for radiocarbon dating.

Experimental Approach

In the case of T'ang Haywen paintings on the Arches®, the feasibility of radiocarbon dating rag (cotton) paper was dependent on the source of cellulose for the paper and complementary art historical information regarding the artist's creative phase. To be able to verify that the Arches® paper can indeed be dated to the year of its production, authentic T'ang Haywen artwork pieces were sampled and analyzed (Figure 1). The selected pieces are free of authenticity question as their creation is well documented to the early 1980s. Following the successful dating of legitimate T'ang Haywen pieces, questioned pieces that appeared on the market only recently (2014) were sampled (Figure 2), and their radiocarbon age was compared against authentic work of T'ang Haywen.

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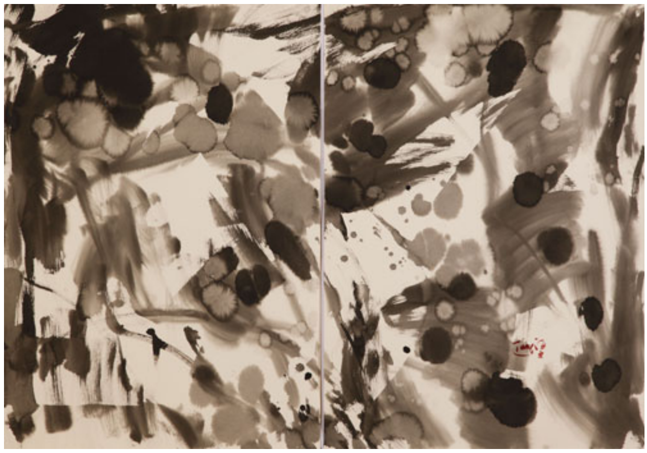

Figure 1 One of the 7 authentic paintings from which sample PK19 was removed.

Figure 2 Sample PK11 was taken from this suspected painting.

Samples of Paper

Strips of paper (ca. 100 mg; ca. 15–10 cm long and ca 0.5 cm wide) from the paintings were cut along the vertical edge of the art pieces, while some of the samples were taken at the corners (Figure 2). Most of the paintings were completed on 2-mm-thick paper, meaning that the pictorial layer did not go through the whole thickness of the paper. Consequently, the top layer of the paper bearing the painted surface was avoided and only the lower part of the paper was sampled for analysis. The total number of samples was 21, which included 7 T'ang Haywen paintings with secured authenticity and 14 paintings that were suspected of being counterfeits. In each case, ca. 100 mg of paper material was sampled, allowing for duplicate analysis if needed. Arches® paper is declared as 100% cotton, although the producer declined to provide complementary information of its composition. Consequently, paper samples were subjected to Fourier transformed infrared spectroscopy (FTIR) analysis. The spectra were collected on PerkinElmer, Frontier FTIR spectrometer, in ATR mode.

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Treatment and AMS Analysis

Before combustion and graphitization, samples were cleaned with solvents: hexane, acetone, and ethanol in a Soxhlet system and with acid and base (0.5M HCl–0.1 M NaOH–0.5M HCl, 60°C each step 1 hr) (Hajdas 2008). The equivalent of 1 mg C of the dried, cleaned paper (2.3–3 mg) was weighed in a tin crucible, rolled and pressed together for combustion in the Elemental Analyser of the automated graphitization equipment AGE (Wacker et al. 2010). The graphite was pressed into the cathode and measured along with the set of standards (Oxalic Acid II and blanks Phthalic acid) using the ETH AMS system MICADAS (Synal et al. 2007).

RESULTS AND DISCUSSION

The samples' suitability for radiocarbon analysis was proven by FTIR analysis, as all collected spectra show absorption bands characteristic of cellulose (Garside and Wyeth 2003). This preliminary analysis confirmed that cotton is indeed the main component of the paper samples under study.

Results of AMS analysis, given as $F^{14}C$ and $\delta^{13}C$, all measured on 1-mg graphite are summarized in Table 1. The calibrated (calendar) ages were calculated using the program CALIB http://calib.org/CALIBomb/) with the post-bomb atmospheric curve (Levin and Kromer 2004; Levin et al. 2013; Hammer and Levin 2017).

It is apparent from the data obtained that the pieces of art genuinely created by T'ang Haywen carry the radiocarbon signature of the 1980s. In particular, painting from which sample TW1 was collected, belongs to the earliest pieces created on Arches® paper. Due to the feature of the bomb peak calibration of $F^{14}C = 1.3094 \pm 0.033$ results in two calendar intervals, i.e., it shows that the paper was made from cotton, which was growing in either in 1957–1958 or 1978–1979 Northern Hemisphere seasons (Figure 3a). However, knowing that the artist began to use Arches® paper only after 1983–1984, which is a very particular type of paper, it is very unlikely that the artist used 25-yr-old material, thus the first interval can be excluded. The result offers interesting information on the aging of the material before being used by the artist. While, the original painting was painted in 1983–1985, calibrated radiocarbon age of TW1 sample yields 1978–1979 for the time of cotton growth. The resulting offset represents a time lag of 5–6 yr, which is a reasonable estimate of the time needed for production and distribution of paper, as a similar offset has been observed for paintings on canvas (Hendriks et al. 2018; Brock et al. 2019). The combination of art historical research and radiocarbon ages allows deeper insight into the artist's world. Knowledge regarding the artist's techniques and habits in choosing and acquiring paper may provide decisive arguments in the interpretation of the results, as some artists preferred older paper for support of their artworks and/or reused older books (Nicholas 2013).

The radiocarbon results on the six additional authentic paintings by T'ang Haywen corroborate their provenances as all were created on paper that carries the ^{14}C signature of the late 1980s (1986–1990; Figure 4).

The 14 paintings acquired in 2014 and suspected to be counterfeit have $F^{14}C$ values higher than 1 but the measured $F^{14}C$ on this set of paintings is significantly lower than the ones judged as authentic. Although, as for all $F^{14}C > 1$ the calibration of $F^{14}C$ results in 1956–1960 and post-1963 intervals, as argued above, the probability that the artist used decades-old Arches® paper

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Table 1 Results of the AMS analysis on Arches® paper. The calibrated (calendar) ages are 2-σ ranges (95.4% confidence limit) and were calculated using the program CALIB http://calib.org/CALIBomb/) with the Post-bomb atmospheric curve (Levin et al. 2013, 2004). As discussed in the text, the first possible interval 1956–1959 can be excluded.

Lab nr.	Sample	$F^{14}C$	1σ	Calendar age (second interval of bomb peak)	Comment*
ETH-73705	TW1	1.3094	0.0033	1978–1979	1983–1985
ETH-74556	PK15	1.1767	0.0030	1986–1990	a
ETH-74557	PK16	1.1709	0.0030	1987–1990	a
ETH-74558	PK17	1.1752	0.0030	1986–1989	a
ETH-74559	PK18	1.1796	0.0030	1986–1990	a
ETH-74560	PK19	1.1701	0.0030	1987–1990	a
ETH-74561	PK20	1.1782	0.0030	1986–1990	a
ETH-74012	PK1	1.0418	0.0019	2009–2011	u
ETH-74013	PK2	1.0404	0.0025	2009–2011	u
ETH-74014	PK3	1.0388	0.0025	2010–2011	u
ETH-74015	PK4	1.0423	0.0025	2009–2011	u
ETH-74813	PK5	1.0374	0.0028	2009–2011	u
ETH-74814	PK6	1.0368	0.0027	2009–2011	u
ETH-74815	PK7	1.0430	0.0028	2008–2011	u
ETH-74816	PK8	1.0410	0.0028	2009–2011	u
ETH-74817	PK9	1.0399	0.0028	2009–2011	u
ETH-74818	PK10	1.0414	0.0028	2009–2011	u
ETH-74819	PK11	1.0425	0.0028	2009–2011	u
ETH-74820	PK12	1.0426	0.0028	2008–2011	u
ETH-74821	PK13	1.0401	0.0028	2008–2011	u
ETH-74822	PK14	1.0373	0.0028	2010–2011	u

*Paintings sold in Paris in 2014. Attributions: a-authentic, u-uncertain.

seems to be low, therefore indicating growing years of 2009–2011 (Table 1). These results are even more striking given that all 14 paintings have identical (within 2σ) $F^{14}C$. Such an observation may be explained by the use of sheets from the same lot of paper. Moreover, the narrow $F^{14}C$ spectrum argues against a potential re-use of old paper produced in the 1950s. If this were the case, the measured $F^{14}C$ would reflect a wider spectrum. The observed coherent results obtained on many recently "discovered" paintings would require T'ang Haywen to have an access to a large supply of Arches paper produced in the 1950s within a short time that was then stored until 1980–1991. Therefore, knowledge about the artist's life and work style, supported by many preserved personal documents, is essential and complementary to our ^{14}C results. In an early stage of his productive life in Paris in the 1950s, T'ang Haywen was too poor to buy expensive paper, let alone many sheets, which is why during this time he used Kyro or equivalent wood-pulp papers. Moreover, additional art historical research convincingly established that T'ang Haywen could not have painted diptychs of an "abstract" subject and on cotton paper during the 1950s.

Figure 4 shows a summary of all the results plotted against the bomb peak. It is evident from our ^{14}C results that the sampled paper from the 14 questioned pieces postdates 1991, therefore, they could not have been created by T'ang Haywen.

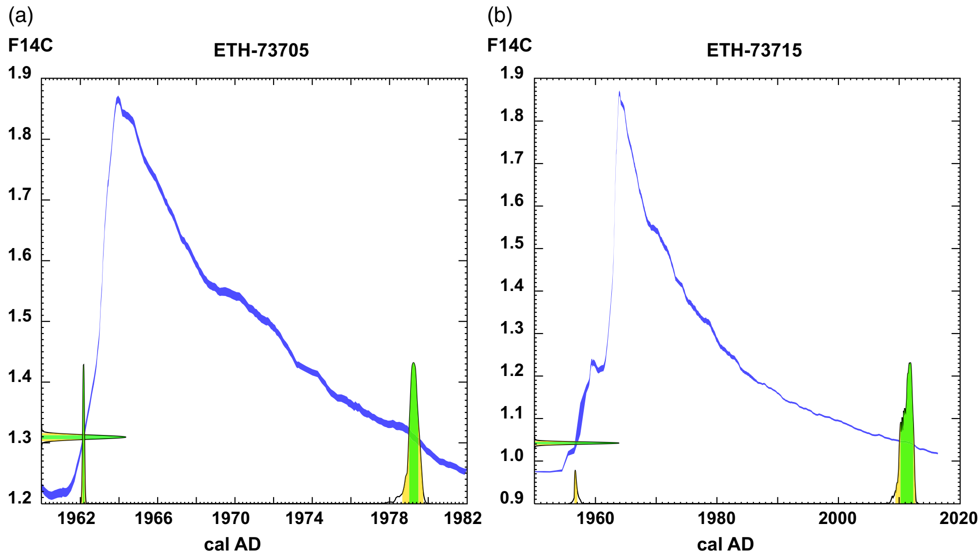

Figure 3 Examples of calibration using CaliBomb and Levin et al. 2013 (smoothing 1.0 yr): (a) ETH-73705 Sample TW1 taken from the early 1980s, genuine painting by T'ang Haywen. (b) ETH-74015 Sample PK4 taken from a fake painting.

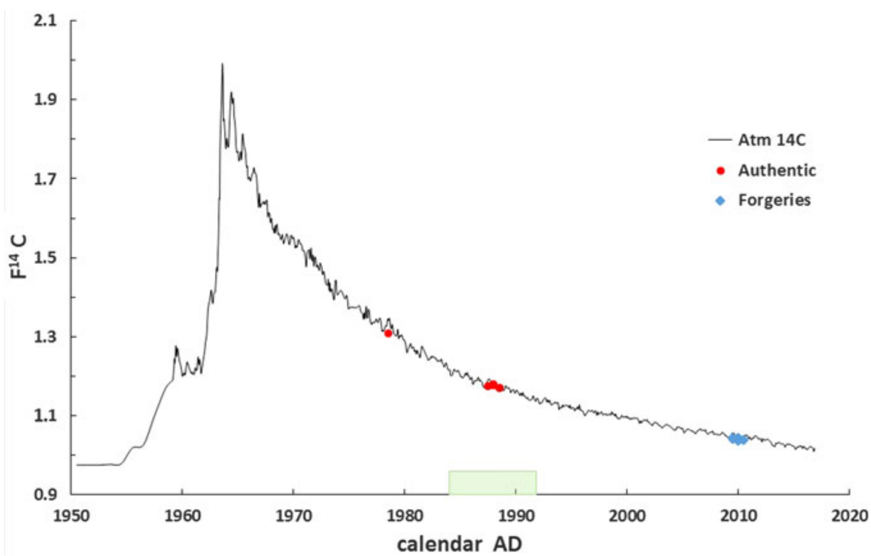

Figure 4 Summary of the results obtained on authentic paintings (red dots) and forged ones (blue diamonds) plotted against atmospheric data of Hammer and Levin (2017); the green box indicates years 1983–1991, i.e., the time when Arches paper was used by T'ang Haywen. (Please see electronic version for color figures.)

SUMMARY

Results of bomb radiocarbon dating of Arches® paper allowed for a clear distinction between authentic and forged paintings of T'ang Haywen. Such results were only possible because two essential conditions were fulfilled: (1) the Arches® paper is made of cotton and (2) the artist

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worked with Arches® paper in years 1985–1991. It has to be stressed that the future of atmospheric ^{14}C, which is becoming extensively diluted with fossil-fuel-derived CO_2, will complicate the straightforward use of ^{14}C dating for the detection of recent forgeries.

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