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# The Long Revolution of Radiocarbon as Seen through the History of Swiss Lake-Dwelling Research

## Summary

This paper reassesses the implementation of radiocarbon dating in archaeology based on the technique's development while researching ancient lake dwellings in Switzerland between 1950 and 1970. The aim is to explain archaeologists'initial failure to accept the results obtained by this method. Two key issues are thereby the core focus of this analysis. The first concerns the disciplinary context that influenced the reception of 14C dating among prehistorians. The second deals with methodological discussions concerning 14C dating and dendrochronology, being radiocarbon dating's most related chronological tool. While dendrochronology and 14C were first complementary in the 14C calibration process since the 1960s, it was then quickly realized that dendrochronology produced more detailed temporal data due to the good preservation conditions of wooden structures at Swiss lake dwellings and thus competed with 14C results. In fact, this competition had to do with the two differing methodologies of data acquisition and time measurement.

Keywords: History of science; 14C; dendrochronology; Swiss lake-dwelling research.

In diesem Artikel soll die Anwendung der Radiokarbondatierung in der Archäologie neu untersucht werden, basierend auf ihrer Entwicklung während der Erforschung der Schweizer Seeufersiedlungen zwischen 1950 und 1970. Ziel ist es zu erklären, warum die Archäologen die durch diese Methode gewonnenen Resultate zunächst nicht akzeptieren konnten. Zwei Schlüsselfragen leiten die Untersuchung: Die erste fragt nach dem disziplinären Kontext, der die Rezeption von 14C unter Prähistorikern beeinflusste. Die zweite bezieht die methodologischen Aushandlungen über C14 und der damit verbundenen Methode der Dendrochronologie mit ein. Während sich C14 und Dendrochronologie seit den 1960er Jahren im Kalibrationsprozess ergänzten, lieferte die Dendrochronologie darüber hinaus Einzeldaten, die gerade im Bereich der Pfahlbauten mit ihrer guten Holzerhaltung der C14-Datierung rasch Konkurrenz machten. Tatsächlich hing diese Konkurrenz mit den unterschiedlichen Arten der Datengewinnung und Zeitmessung zu tun.

Keywords: Wissenschaftsgeschichte; 14C; Dendrochronologie; Schweizer Pfahlbauforschung.

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## 1 Introduction

American researchers developed the 14C dating method about 1950. In the last decades of the twentieth century, methodological handbooks and historical accounts of archaeology promoted this as a highly valuable tool – particularly with regard to the revision of Neolithic and Bronze Age chronologies in Europe and to the understanding of cultural change during these periods.[1]

However, this literature has tended to characterize the development of the method as linear in its trajectory and constant in its effects. For example, Colin Renfrew has reinforced this view by focusing primarily on the heuristic impact of the method on the development of archaeological thought.[2] This leading British archaeologist and early proponent of the 14C dating method used the word "revolution" to describe the invention, arguing that the scientific community experienced a paradigm shift with regard to the interpretation of cultural change once it had embraced the reliability of 14C.[3] Needless to say, this description of the archaeological community's reception of the method is partial – it represents the point of view of one archaeological radiocarbonist.

The historiography of radiocarbon dating has tended to focus on the success of the method as well as on its heuristic significance for the development of archaeology, emphasizing revolutionary moments of methodological innovation. Moreover, due to their common interest in promoting a linear and progressive narrative of archaeological practice, the authors of these publications draw a stark dividing line between archaeology before and after radiocarbon.[4] As Renfrew puts it:

> Sixty years ago, it was in general not possible to date archaeological finds with precision unless these could be related to one of the historical calendars, whether Egyptian, or Chinese or indeed Maya. Vast parts of the globe lacked any secure chronology. Dating was nowhere possible before about 3000 BC. Now a secure chronology is available everywhere, so long as organic materials are available for dating.[5]

1 Renfrew 1973; Stöckli 1986, 13.
2 Renfrew 1973.
3 Renfrew 1973; Renfrew was not the first one to use this term. In 1952, O.G.S. Crawford, the editorialist of the British journal *Antiquity*, talks about a "revolutionary discovery" (Crawford 1952, 177).
4 E. g. Evin and Oberlin 1998; Renfrew 1973; Renfrew 2009.
5 Renfrew 2009, 122.

This historiography also suggests that, once they appeared, the results produced by this method were quickly accepted without dispute. Such a one-sided historiography has many shortcomings. First, though this literature generally emphasizes the origin and development of radiocarbon in laboratories and the results contributed by this tool to the study of prehistory, it has not sufficiently documented the processes by which the prehistorians adopted this tool during the second half of the twentieth century. Second, the socio-political context surrounding the production of this method in the 1950s has not been accounted for, despite the decisive role it played in the rapid pace of development and diffusion.[6] Third, the disciplinary historiography has misrepresented the long lapse of time between the invention of the method and the recognition of its results by members of the archaeological community. In other words, this historiography does not give a satisfying description of the relationship between the tool and its potential users – in this case archaeologists. Finally, the integration of dendrochronology into the calibration of 14C is generally treated as a mere technical detail, which obscures the important role this second method played in the gradual acceptance of radiocarbon dating by archaeologists.

Based on an analysis of the development and reception of 14C and dendrochronology in Swiss lake-dwelling research,[7] we seek to explain the gap between archaeologists' recognition of the methodological innovation and their acceptance of results thereby obtained. After 1854, when the first lake-dwelling settlements were discovered by the antiquarian Ferdinand Keller, such settlements quickly became a very popular domain of research.[8] Given the wet atmosphere of these areas, organic remains – including those of wood constructions, seeds and plants – were very well preserved, which encouraged naturalists and archaeologists to collaborate. Since the 1950s, the excellent conservation of such organic remains has enabled 14C and dendrochronology to be used in parallel. Focusing on the period between the 1950s and the 1970s, our analysis hinges on two key issues. The first concerns the disciplinary matrix – between the humanities and the natural and exact sciences – that influenced the reception of 14C among prehistorians. During this period, Swiss prehistorians tried to stabilize their discipline and to improve its standing among the sciences. Collaborations with natural and exact sciences were seen by some prehistorians as a mean of reinforcing their own discipline. The seductive power of the 14C method was particularly strong due to its origin. Alliances between prehistory and nuclear physics were also highly regarded by the National Science Foundation. The second issue involves the methodological negotiations between 14C and dendrochronology.

6 There are some exceptions, however, which mostly concern the history of the method in the United States. Marlowe 1980; Marlowe 1999; Nash 1999; Nash 2000. Regarding Europe and Germany, also see Billamboz 2004.

7 Delley (in press).

8 Kaeser 2004.

We pursue two avenues of analysis in what follows: one structural, and the other biographical. Regarding structure, we will situate the development of the method in preexisting political and social contexts (i. e. the pacification of nuclear research programs after WW II), and related, though external, technical innovations (i. e. dendrochronology for the calibration of 14C) that played a decisive role for the stabilization of 14C in the field of archaeology. In particular, we will tackle the structural features of the allied disciplines (nuclear physics and botany) involved in the development and application of the method in archaeology, as well as the epistemic impact of dendrochronology's ability to inscribe probabilistic time upon a "real-year" calendar. The biographical point of view aims at shedding light on the fate of these two methods in the daily practice of archaeology. The ways in which archaeologists reacted to this innovation differed depending on their personal epistemological orientations and research backgrounds.

## 2 Diabolizing Milojčić and making dissidents invisible

According to the disciplinary historiography, the entire archaeological community quickly accepted radiocarbon as a decisive tool. Only one European prehistorian is supposed to have resisted: the German archaeologist Vladimir Milojčić. A professor of prehistory at the University of Heidelberg, Milojčić published a book in 1949 on the chronology of central and south-western Europe,[9] which he had established using the common archaeological method of cross-dating. Like many of his contemporaries, Milojčić combined a diffusionist perspective on the question of culture change with the study of artefact assemblages in closed contexts such as tombs. If these contained objects imported from Egypt, Crete or Greece – cultures that used texts and calendars before the rest of Europe – this provided archaeologists with a means for building absolute chronologies. But even early radiocarbon evidence called these archaeological chronologies into question, and with the advent of calibrated dates in the mid-1960s, this interpretative system was further eroded.[10] If Milojčić had criticized the new method with good reason, his skepticism can't be interpreted merely as an ideological rejection of a high chronology for the Neolithic and the early Bronze Age in Europe. In rejecting this possibility, Milojčić was seen by radiocarbonists as someone who either didn't want to put forth the effort to understand the details of radiocarbon dating, or as a narrow-minded traditionalist who refused to engage with specialists from other disciplines.[11] His opposition, however, stemmed from different issues, among them, the power dynamics between archaeology (assigned to the humanities) and the natural and exact sciences. He developed his objection in an article published in *Germania* where he clearly

9 Milojčič 1949.

10 See Ferguson, Huber, and Suess 1966.

11 Schwabedissen and Münnich 1958.

expressed his opposition to the monopolization of crucial chronological questions in archaeology by the radiocarbon method.[12] Even if Milojčić was the most visible representative of the opposition to the 14C method in archaeology,[13] it appears that many of his contemporaries were also skeptical, though they were less vocal or simply declined to state their position. The unreliability of the results obtained by the 14C method in those years was a primary cause of such resistance. Another point was certainly, as Milojčić pointed out, the fact that archaeologists already had their own dating methods; as long as the new approach didn't deliver reliable results, i. e. results in accordance with archaeological chronologies, there was no need to give too much weight to the 14C dates. Nevertheless, as mentioned above, archaeologists did take notice of this innovation. Moreover, the seductive power of 14C, as well as of the natural and exact sciences, remained decisive for archaeologists.

## 3 The relationships between the sciences around and after the 1950s

The establishment of the 14C dating method in America was facilitated by nuclear research infrastructures and the competencies of scientists involved with the military-industrial complex. The context of the Manhattan project, which led to the fabrication of the atomic bomb, was especially significant in this regard.[14] Beginning in the late 1940s, many scientists specializing in nuclear physics found new research opportunities in the development of non-military applications – for example, in medicine, agronomy, energy production, and isotopic dating methods. In most industrialized countries, governments subsequently invested in these domains, a move that is exemplified by the political program "Atoms for Peace", launched in mid-1950s America. In Switzerland, politics and science were similarly linked in the case of the National Science Foundation, where a fund was specifically created in 1958 for financing basic and applied research in the nuclear domain. From 1945 until this date, nuclear research had been overseen by a Commission for atomic science, which depended directly on the Swiss government for financial and scientific support.[15] Such massive investments furthered and contributed to the diversification of several disciplines – archaeology, geology, climatology, and botany among them – and led, notably, to the 1957 creation of a radiocarbon laboratory in Berne, entirely financed by the National Science Foundation. Fully integrated with the knowledge-production regime which was implemented during the

12 Milojčič 1957.
13 Milojčič 1957; Milojčič 1958; Milojčič 1959; Milojčič 1964.
14 Marlowe 1980; Marlowe 1999.
15 Joye-Cagnard 2010, 118.

Cold War in the framework of nuclear pacification programs, "a grouping of institutions, beliefs, practices, politic and economic regulations which delimitates the mode of being sciences",[16] the 14C dating method has, since its origin, had significant social and cultural authority among the sciences.

State administration and control beginning in the middle of the twentieth century changed the relationships between the humanities and the natural and exact sciences in a way never witnessed before. Indeed, most industrialized nations developed government-supported institutions responsible for administrating scientific research between the interwar period and the 1950s. The structuring effects of such institutions – the *Centre national de la recherche scientifique*, the *Deutsche Forschungsgemeinschaft*, the National Science Foundation in Switzerland and Belgium, among other examples – were important. Concretely, while these institutions were created to support science, especially in the domain of basic research,[17] they also defined priorities and norms that were intended to accommodate new expectations regarding the relationship between science and society.[18] In addition, they incorporated new categories of actors (administrators and policy makers, for example), and this modified the position of scientists and the place of science in competitions among nations. In such competitions, roles for the humanities and sciences clearly emerged. For a discipline like archaeology, alliances with well-established and authoritative sciences, such as physics, helped increase both the authority of the discipline and its visibility among scientists and the general public.[19]

Besides promising to yield knowledge in the domain of prehistory, collaborations between archaeologists and physicists were also thought to be a way of increasing the scientific status of results at a time in which procedural reproducibility and quantitative methods were so important. The establishment of a 14C laboratory in Bern in 1957 reveals such interests: In this case, the prehistorian Hans-Georg Bandi (1920-) initiated alliances with physicists for precisely these reasons. Together with Max Welten, a botanist with similar interests in 14C dating, and the nuclear physicist Hans Oeschger, Bandi created a 14C laboratory at Bern's Institute of Physics.[20] What is more, from 1957 on, they managed to obtain the support of the National Science Foundation, which encouraged archaeologists in the use of this method. Through 14C dating, archaeology thus benefitted directly from the powerful position physics, and in particular nuclear physics, occupied among the sciences after World War II.

Archaeologists also characterized the use of natural scientific evidence in prehistoric research in terms of its modernity, despite the fact that such evidence had been in

16 Pestre 2003, 35. – Translation by the author.

17 Fleury and Joye 2002.

18 Concerning the influence of the Swiss National Science Foundation on the development of Swiss archaeology, see Delley 2013.

19 Bourdieu 2001, 134.

20 Archives of the Swiss National Science Foundation, Bern. Application no. 962 (H.-G. Bandi and M. Welten), 16.5.1956. Division I; Application A 42, Intermediate report 1.4. 1959-31.3.1960, 11.4.1960. Division II; Application A 228, 7.6.1962. Division II.

circulation since the 1860s.[21] In the field of wetland archaeology, the 1954 centennial anniversary of the discovery of the lake-dwellings presented a good opportunity for touting the newfound scientific quality of this field of research. Walter Guyan (1911–1999), who excavated an important lake-dwelling settlement at Thayngen-Weier and was in charge of editing *Das Pfahlbauproblem* (The Lake-Dwelling Problem), the book published in honour of the commemoration, clarified in the introduction to the volume that the authors "tried to discuss the problem taking into account in particular the progresses of the methods and of the '*Hilfsmitteln*'" – namely those tools stemming from the natural sciences.[22] Emil Vogt (1906–1974), curator at the Swiss national Museum and professor of prehistory at the University of Zurich, was heavily involved in the publication of *Das Pfahlbauproblem*,[23] in which the first 14C dates concerning Swiss prehistory were published. Vogt deliberately emphasized in a letter to the book's editor that "this volume is *not* a commemorative volume, but a collection of more scientific works on the lake-dwelling problem".[24] This generation of prehistorians underlined the modernity of their research by drawing attention to the use of "scientific tools" derived from the natural and exact sciences. Presenting prehistory as a multidisciplinary field of research was all the more important when such a definition was one of the priorities articulated by the new scientific administration. Depicting prehistory as a unified element within modern science as a whole became part of the rhetoric chosen by members of the National Science Foundation to exemplify a new way of practising scientific research:

> In recent decades, a new 'style' of research has been affirming itself in many areas of science. Major projects can no longer even "get off the ground" without cooperative work from veritable groups of scientists: a result of ever increasing specialization. The business of an excavation, for example, was in the last century the work of someone such as Schliemann, assisted by his wife and a few faithful handlers of the pick and shovel; today it is necessary that the archaeologist and the prehistorian collaborate with the physicist (in physical procedures to determine dates), with the botanist (in pollen analysis), with the specialist in dendrochronology (in the determination of annual layers in the trunks of trees), with the parasitologist (in the determination of the internal parasites of the inhabitants), with the entomologist-archaeologist (in the determination of insects for prior periods), with the palaeontologist and with the chemist.[25]

The scientific tenor of these excavations was also thought to provide a guarantee of objectivity. It became necessary for these scholars to emphasize field observations and empiri-

21 Kaeser 2011.
22 Guyan 1955. – Translation by the author.
23 Vogt 1955.
24 Letter Vogt to Guyan, 14.7.1954, Correspondence Vogt. Swiss National Museum Zurich. – Translation by the author.
25 Von Muralt 1963, 13. Thanks is due to Yan Overfield Shaw for translating the quote.

cal data collection, rather than interpretation. This helped them to establish boundaries between their own research practices, which they defined as modern and scientific, and those of previous generations of antiquarians and amateurs, reaching back to the nineteenth century. This supposedly more objective approach, focusing on concrete facts, was on display in a documentary entitled *Lake Dwelling Research in Switzerland*.[26] This film was ostensibly produced for the same commemorative purposes as the 1955 volume entitled *Das Pfahlbauproblem*. Unlike the book, however, it was intended for a wide public including amateurs as well as specialists. The documentary produced by the archaeologist Hans-Georg Bandi devoted considerable space to issues of methodology and procedures, and was filmed in such a way as to emphasize the scientific nature of Swiss archaeology. Steps taken by archaeologists and naturalists in the film were depicted as inerrant and systematic, while interpretive discussions of their findings are almost entirely absent, leaving even more place for empirical observations. The promotion of objective practices made it possible to counterbalance the subjective dimension of the debate regarding the position of the lake-dwelling villages, a debate which has taken place between German and Swiss archaeologists since the 1920s.[27]

Regarding the institutionalisation of 14C, the creation of a laboratory in Bern – which benefited, as we have shown, from the Swiss government's massive financial investment in nuclear research – anticipated what would become a common implementation of the method in archaeology. While the method was developed between 1949 and 1955, for a significant number of Swiss archaeologists its utility and necessity was still not yet obvious at the end of the 1950s. The expense of radiocarbon dating was a significant obstacle for archaeologists. However, with support from the National Science Foundation, they were able to reap the benefits of free dating – given that the laboratory itself was financed by the same institution. In this way, the National Science Foundation indirectly promoted the use of 14C amongst archaeologists. Nevertheless, there were relatively few demands for archaeological determinations between 1957 and the 1970s, as compared with requests for botanical and geological samples.

In sum, if the pragmatic and positivist rhetoric of Swiss archaeology could be fulfilled by scientific procedures imported from other domains – physics, geology, botany – practitioners continued to interpret 14C results with caution. In truth, the results obtained by the method were imprecise and inconsistent; laboratories in this case do not appear to have mastered the situation, despite claims to the contrary.

26 Bandi 1960.

27 See Rückert 1998, 87–88; Kaeser 2004, 107–108.

## 4 Concepts and categories are discipline-bound

There were other important reasons why the collaboration between different parties involved in the development and application of the method faltered. First, physicists and archaeologists did not agree on the meaning of a reliable method, and, by extension, a reliable date. While the ability to reproduce measurements on different equipment was a primary concern for physicists and chemists, from the point of view of archaeologists, the result of the measurement had no value in itself; rather it only took on meaning in an archaeological context. Unlike physical scientists, who believed that a date could be published as soon as it had been obtained in independent laboratory contexts, archaeologists maintained that the value of a result could only be established within the context of archaeological observation – involving stratigraphy, cultural-historical comparisons, and typology, for instance. A 14C date would be judged true or false only on the basis of its correspondence to results from these other domains, which were the tools archaeologists had traditionally used to establish their chronologies. These two different conceptions of what constituted acceptable methodology were not readily compatible, and this misunderstanding had far-reaching disciplinary ramifications that bring us back to the complexity of collaborations between natural sciences, exact sciences, and the humanities.

Second, as already mentioned, archaeologists had long presumed 14C dates to be true only in cases where these dates could be corroborated by archaeological chronologies. If 14C dates called these traditional chronologies into question, the dates tended to be ignored and were not included among archaeological results. Until the 1970s, when the first calibration curve was produced, archaeological chronologies were the primary means for verifying the reliability of radiocarbon dating in the absence of historical calendars – among laboratory researchers as well as archaeologists. This explains why, for three decades following the first tentative use of radiocarbon dating, prehistorians published essentially uncalibrated radiocarbon dates which more or less corresponded to archaeological chronologies, without estimating equivalencies in calibrated, i. e. calendar years. Such calibrated results nevertheless became available in the mid-1960s,[28] but they indicated that the European Neolithic was much older and had lasted much longer than archaeologists had been able to establish on the basis of traditional methods alone. In 1970, measurement of Neolithic piles at Auvernier-La Saunerie confirmed a new high chronology of the European Neolithic,[29] but despite Swiss prehistorians'

28 Ferguson, Huber, and Suess 1966.

29 Suess and Strahm 1970. – The results published by Ferguson et al. in 1966 were based on the measurement of the Neolithic piles of Thayngen-Weier and Burgäschisee, two Middle Neolithic sites (Pfyn and Cortaillod cultures) of Switzerland. The results obtained were 3700 and 3760 $\pm$ 40 BC, which means 1000 years older than the uncalibrated 14C dates (Ferguson, Huber, and Suess 1966, 1177). In 1970, the Neolithic piles of Auvernier-La Saunerie measured using the 14C method and subsequently calibrated were assigned to Late Neolithic levels. The

familiarity with questions of dendrochronology, references and commentaries regarding these new results were rare. To understand this wait-and-see attitude, we must first consider the fact that the community of prehistorians didn't believe in such high dates – which means a middle Neolithic beginning around 3600 BC instead of 2600 BC – and preferred to ignore them.[30] Indeed, Swiss prehistorians were waiting for these new dates to be confirmed by the continuous oak dendrochronological referential curve. The German botanist Bruno Huber had started to build this referential curve in the 1940s[31] based on measurements of oak wood samples taken from historic and prehistoric buildings in Southern Germany and in Switzerland. Many Swiss archaeologists who were involved with the excavation of lake-dwelling settlements from the 1950s onwards took part in this project. This referential curve, on which each oak dendrochronological curve produced for prehistoric settlements had to be correlated in order to date the settlements in real years, would not be established until the middle of the 1980s.[32] Until this date, Swiss archaeologists maintained that new 14C chronologies had to be taken with precaution. So there was a clear discrepancy between, on the one hand, the development of the method and its implementation, and, on the other hand, the full-fledged acceptance of its results, signalled by their integration into archaeological reasoning.

## 5 A genuine interest in naturalist methods, but doubts about 14C: Emil Vogt

The tentative attitude archaeologists showed towards 14C results did not derive from a refusal to collaborate with other disciplines. The case of Emil Vogt is a good example. Vogt debated the question of method, and, given his position as curator at the Swiss National Museum and professor at the University of Zurich, his views had considerable influence. In the context of lake-dwelling excavations, Vogt did not hesitate to assert his point of view when excavators failed to adhere to procedures he had mandated concerning the surface of the excavations, the documentation of discoveries, and especially the drawing of archaeological remains *in situ*. Like German prehistorians active in the domain of *Moorarchäologie* (archaeology of marshes) – Gustav Schwantes,[33] Hans Reinerth[34] and Hermann Schwabedissen[35] – Vogt believed in the potential of palynology, botanics and (since the 1950s) dendrochronology as means of furthering knowledge about lake-dwelling settlements. Vogt was especially interested in the question of the

result obtained was 2400 BC instead of 2000 in uncalibrated years.

30 Drack 1969; Stöckli 1986, 13.

31 Huber 1941; Huber and Jazewitsch 1958.

32 Becker, Billamboz, and Egger 1985.

33 Schwantes 1939.

34 Reinerth 1940.

35 Schwabedissen 1949.

positioning of the lake-dwelling settlements, which he situated on the shore and not in the lakes.

The first 14C dates obtained in Copenhagen on the basis of Swiss prehistoric research, came from the settlement of Egolzwil 3, a site Vogt identified as the most ancient Neolithic settlement in Switzerland following excavations there at the beginning of the 1950s. The impulse to date samples from Egolzwil 3 didn't come from Vogt himself, however, but from the Danish sedimentologist and botanist Jens Troels-Smith, a member of the *Moorlaboratorium* at the National Museum of Copenhagen. Troels-Smith, who had been collaborating since the beginning of the 1950s with Vogt and other Swiss archaeologists who were part of his circle – especially Josef Speck, Walter Guyan, and Hans-Georg Bandi – was interested in Egolzwil 3 due to its presumed high antiquity. With the 14C determinations he sought to establish whether the Swiss Neolithic was older or younger than the Danish Neolithic. Troels-Smith had already studied botanical evidence coming from these two areas, and had also established palynological calendars for Switzerland and Denmark. 14C measurements would now date such climatic and environmental events absolutely, and further, would determine when neolithization, as a cultural and social event, occured in both of these areas.[36]

While Vogt admired Troels-Smith's methods of observation compared to the approaches of other Swiss botanists, which he found a bit outdated[37] – he nevertheless remained cautious about the results provided by 14C determinations. Regarding the first results obtained at Egolzwil, Vogt said:

> Your first radiocarbon dates contain a very large margin of error. I wouldn't dare to calculate an average from these two results. In itself, the date of 2600 would fit well, whereas the date of 3200 looks too old. I agree with you when you say that it is too early for concluding anything from these two measurements.[38]

Hence, it is no surprise that when Hans-Georg Bandi asked Vogt to furnish some archaeological wood samples from the Swiss National Museum in 1954 – his aim being to calibrate new equipment at the laboratory in Bern – Vogt answered that recent communications published on the method were far from satisfactory. He mentioned in particular the dating of the site known as Zug-Sumpf, which Frederik Zeuner derived at the University of London, as well as the results obtained for Egolzwil 3 and Thayngen-Weier.[39] It is important to note that Vogt's position was not unique. Reviewing the 14C dates of Egolzwil 3, the prehistorian Marc-Rodolphe Sauter also emphasized that the 14C dates

**36** Troels-Smith 1955; Troels-Smith 1956.
**37** Letter Vogt to Guyan, 12.5.1952. Correspondence Vogt. Swiss National Museum Zurich.
**38** Letter Vogt to Troels-Smith, 5.3.1953. Correspondence Vogt. Swiss National Museum Zurich. – Translation by the author.
**39** Letter Vogt to Bandi, 21.5.1955. Correspondence Vogt. Swiss National Museum Zurich.

didn't fit well with the shallower chronology most prehistorians had adopted: Sauter believed that many cross-checks needed to be done in order to satisfy archaeological and naturalist requirements.[40] Thus, despite his profound interest in applying the natural sciences to prehistory, on the questions of chronologies, Vogt didn't expect much of the 14C method. Like many contemporary archaeologists, his epistemological orientation when it came to dating methods was oriented towards typology and cross-dating. For Vogt, results brought by physicists should first confirm the chronologies established by archaeologists before their contribution to the business of archaeology could be evaluated properly.

## 6 Reconciling two conceptions of time

Alongside archaeological chronologies, dendrochronology became a second safeguard for archaeologists using 14C methods – both in the context of lake-dwelling research and in archaeology more generally. As a method that was external to archaeology, dendrochronology revealed 14C inconsistencies. Moreover, in the 1960s this method became the most expedient way to transform 14C dates into real calendar years and has remained so ever since. The symbolic capital of dendrochronology was thus reinforced, just as its potential to generate highly precise dates had already been recognized.

In the eyes of archaeologists, dendrochronology and 14C didn't have the same heuristic potential. Since the mid-1960s, dendrochronology had been central to the interpretation of lake-dwelling villages – it contributed to the production of detailed relative chronologies of settlements, the restitution of different phases of construction, and the analysis of phases of abandonment and occupation, to name some examples – whereas radiocarbon had primarily been a means of obtaining an average dating of the different phases of occupation witnessed by a given a settlement.[41] And while archaeologists didn't expect precise results from the radiocarbon method, they were also aware of its inaccuracy: "We will convince physicists and also some archaeologists that for once archaeological pieces of evidence about relative continuities are more evident than their measurements."[42] In Feldmeilen-Vordefeld, Twann and Auvernier-La Saunerie archaeologists clearly exposed these problems by comparing the results of dendrochronology with those of 14C.[43] The critical benefit of dendrochronology, as compared with 14C hence became greater and greater in a wetland context. For archaeologists such as Alasdair Whittle and Jean-Paul Demoule, 14C gives a false impression of continuity within

40 Sauter 1955, 152.
41 Furger 1980; Gallay 1965; Schwab 1989.
42 Winiger 1976, 55. – Translation by the author.
43 Winiger 1976; Furger 1980; Schifferdecker et al. 1989, 25.

a site occupation and between different cultural phases due to the margin of error accompanying each date.[44]

Nevertheless, the relationship between 14C and dendrochronology was not a struggle between two absolute dating methods. The disagreement between these two methods had rather to do with the differing conceptions of time they reproduced. While archaeologists faced difficulties with the interpretation of 14C time, which was cast probabilistically, dendrochronological and archaeological time could easily be compared, given that the unity of time – one tree ring produced annually – corresponded directly to the rhythm of an annual calendar. This was true despite the fact that archaeologists did not immediately gain access to an absolute dating method. Indeed, until the end of the 1970s, dendrochronology only yielded *relative* dating means.

One of the specific qualities of the method that was quickly appreciated by archaeologists was that it could, in a best-case scenario, measure time within an error margin of one year. This meant that archaeologists could measure the durations recorded in prehistoric materials – piles and timbers used in building and renovating prehistoric villages, as well as diverse artefacts made of wood – to an accuracy of a few years, which was uncommon for this kind of research. The many different construction and renovation phases witnessed by these settlements could thereby be revealed. Moreover, given the high precision of the dating process, the analysis of wood could provide archaeologists with a relative calendar of the occupations and abandonments of the sites that could be compared with environmental data (e. g. climatic changes, lake levels) and also with archaeological calendars (typology, artefact importations, cultural changes, and the like). The ability to establish, within a short period of time, regular phases of occupation and abandonment along the lakeshores caused by high water periods constituted a decisive conceptual change in the interpretation of the lake-dwelling settlements.

Furthermore, dendrochronology motivated archaeologists to explore several of the cultural, social and historical choices made by prehistoric people more fully than the radiocarbon method. The analysis of wood provided insight into the priorities of lake-dwelling builders with regard to the age, size and species of the trees that were chosen. By regrouping pieces of wood according to felling year and examining the ways in which trees grew, dendrochronologists could classify trees that came from the same zones in tandem. The repetition of such observations, correlated with current botanical observations in the forests, confirmed that prehistoric people controlled and managed their forests, which in turn pointed to territorial organization in timber cultivation. This may well have led to inter-settlement organization, which made it possible to study prehistoric occupation in a large zone such as Auvernier Bay, excavated between 1969 and 1975. The cultural dimension of dendrochronological time was that much more significant in the 1960s and 1970s, when the study of relationships between man and his natural

44 Whittle 1988; Demoule 1995.

environment became a renewed source of preoccupation within contemporary society as well.

## 7 When wood produces effects

Toward the end of the 1950s, the popularity of dendrochronology in lake-dwelling research was on the rise. However, in the context of non-wetland archaeology, where wood was rarely preserved, dendrochronology had not been at issue. Archaeologists in non-wetland environments thus had much higher expectations for the 14C method. In fact, increasing disappointment was also more strongly felt in this milieu, especially when the results delivered by the 14C method failed to match archaeological assumptions. However, as mentioned before, archaeologists who dared to take a clear position on the method were few, and rather than unleash a critical explosion in print, they protested via a "silent mutiny".[45] This phenomenon can be seen indirectly from the large number of articles published by radiocarbonists during the second half of the 1950s (written either by physical scientists or by archaeological devotees) intended to convince skeptics to make use of the 14C method, despite some methodological difficulties laboratory workers were still trying to understand.

From that time on, the role of dendrochronology became decisive for the stabilization of the 14C method. When physicists at the end of the 1950s discovered that the amount of 14C had not been constant in the atmosphere over time, it became obvious that all the dates obtained by this method were in need of correction. Dendrochronology appeared to be the best solution. Samples of prehistoric woods from living *sequoia gigantea*, living and fossilized *pinus aristata* from California, and prehistoric oak piles from Swiss lake-dwelling settlements were sent to 14C laboratories in Europe (Heidelberg, Copenhagen, and Groningen) and America (e. g. La Jolla, where a special program on 14C calibration was started at the end of the 1950s). Such "trading zones",[46] in which collaborations among archaeologists, dendrochronologists and physicists intensified over time, provided radiocarbonists with an "artificial reality"[47] – a calibration curve by which calendar dates eventually could be obtained. This new curve yielded results in a time that could finally be understood by archaeologists in real solar years. In other words, prehistoric wood was an intermediary: through processes of calibration, it helped translate probabilistic time into a historical or calendar time accessible to archaeologists.

However, the contributions of dendrochronology were not limited to the calibration process. Dendrochronology also afforded archaeologists an opportunity to recon-

45 Callon 1986, 201.

46 Galison 1996.

47 Galison 1996, 142–151.

cile themselves to the 14C method, which experienced many set-backs in these years and produced inconsistent results that archaeologists did not take seriously. While physicists tried to suggest the method was under control[48] and required only minor adjustments, some prehistorians, who upheld the reliability of the method, tried to harmonize two worlds separated by an epistemological boundary. The role these archaeologists played in such transformation processes corresponds to Latour's translator.[49] Among them were Harm Tjalling Waterbolk (1924-), who trained as an archaeologist and a botanist in Holland and spent his mature career at the Biologisch-Archaeologisch Instituut in Groningen, and Hanjürgen Müller-Beck (1927-), who trained at the University of Tübingen as a specialist on the Palaeolithic with a strong naturalist orientation. Both emphasized in the 1960s that archaeologists had to have reliable results in order to trust the method. But in light of the fact that significant work had yet to be done before the method could produce reliable results, it was deemed important to keep archaeologists informed about it and to try to convince them, despite the situation, that 14C could be useful in the field of archaeology. To achieve this, Waterbolk and Müller-Beck used very concrete case studies to demonstrate the potential of the method.[50] Such examples contrasted with the theoretical ones physicists used.

Müller-Beck's demonstration regarding the 14C results obtained from the important lake-dwelling settlement at Burgäschisee is telling.[51] Müller-Beck tried to reconcile these results with other methods commonly used in prehistory (typological, botanical, and stratigraphic) in addition to dendrochronological evidence. Marshalling these various tools, Müller-Beck tried to relativise the importance of absolute dating in archaeology by turning the discussion towards the questions of duration – which he understood to fit better with archaeological observation[52] – rather than fixing the debate on the question of the precision of the 14C results, as was usually the case. At stake in his demonstration were not precise dates, but rather reliable durations that were not competing with archaeological chronologies. In other words, Müller-Beck tried to familiarize archaeologists with dendrochronological time, in order to steer their expectations towards the 14C method. Despite this interesting perspective, Müller-Beck's way of conceiving time remained mostly limited to the context of lake-dwelling research, where dendrochronology was always more closely aligned with the archaeological approach, and especially with the interpretation of the settlements. Given the subsequent development of dendrochronology in this context, it continued to be easier to relativize 14C here than in dry-land archaeological contexts.

48 Broecker and Kulp 1956; Barker 1958.

49 Latour 2005, 37. – As translators, these intermediates tried to convince different actors – archaeologists who were not convinced by the method – in order to rally them behind the common cause of stabilizing the 14C dating method in the field of archaeology.

50 Waterbolk 1960; Müller-Beck 1961.

51 Müller-Beck, Oeschger, and Schwarz 1959.

52 On this question see also Olivier 2001.

## 8 Conclusion

Before the 1970s, 14C dating did not satisfy the archaeological community. Even though the German archaeologist Vladimir Milojčić has usually been thought to be the only figure to resist the method, many sceptical archaeologists remained silent and are thus absent from disciplinary histories of the method. Based on the analysis of the reception of 14C within Swiss lake-dwelling research, this paper has aimed to shed light on why 14C continued to seduce members of the archaeological community despite obvious problems. In the 1950s, new expectations defined by the norms and priorities of scientific administrators were increasingly appropriated by archaeologists, who took over the promotion of the sciences in prehistory. But the situation was still more complex. If the power dynamics between the humanities, natural sciences, and exact sciences encouraged some archaeologists to highlight their collaborations with other research domains beginning in the 1950s, they remained tentative when it came to 14C results. In fact, these results could call traditional archaeological chronologies into question. Dendrochronology, however, produced accurate durations rather than absolute dates, and thus was not in direct competition with archaeological chronologies. The dendrochronological approach to temporality grew increasingly popular among prehistorians working in the field of wetland archaeology. Distinct from the kind of results archaeological chronologies could produce, dendrochronology also opened up new dimensions in the interpretation of archaeological time, both from a material *and* cultural perspective. Furthermore, through the calibration process, dendrochronology came to play a decisive role in the recognition and stabilization of 14C in the context of archaeology. Its power to translate radiocarbon calendars into calendar years has progressively helped archaeologists reconcile themselves to the 14C method.

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