*Radiocarbon* (2026), **68**, pp. 431–435
doi:10.1017/RDC.2026.10194

CAMBRIDGE UNIVERSITY PRESS

DATE LIST

# Radiocarbon ages of the Iceman—Reopening a jar with the frozen tissue stored at the ETH laboratory

Irka Hajdas[1] and Duygu Saracoğlu[2]

[1]Laboratory of Ion Beam Physics, ETH, Zurich, Switzerland and [2]University of Basel, Switzerland
**Corresponding author:** Irka Hajdas; Email: hajdas@phys.ethz.ch

**Received:** 20 September 2025; **Revised:** 06 December 2025; **Accepted:** 12 December 2025; **First published online:** 19 February 2026

**Keywords:** frozen tissue; Iceman

**Abstract**
We report the results of radiocarbon dating performed at the ETH laboratory on soft tissue of the mummified body found in September 1991 on the Hauslabjoch in the Ötztaler Alps (near the Similaun Mountain), South Tyrol. Over the past three decades, additional analyses of the sample, which had been stored frozen in a glass jar, have improved the precision of the first published radiocarbon ages. The frozen jar and the story of a mummified body found in the Alps fascinated visitors to the laboratory, mostly primary and high-school students. As part of educational projects, 11 samples were prepared and analyzed, yielding a combined radiocarbon age of 4525 ± 7 BP. This agreement with 4550 ± 27 BP, i.e., the very first results by Bonani et al. (1994), highlights the quality of the analysis performed decades ago. The combined age of all the $^{14}$C ages measured at the ETH laboratory is 4527 ± 7 BP.

## Introduction

On 19 September 1991, the spectacular find of a mummified body frozen for thousands of years at an altitude of 3200 m made Austrian and international headlines. A tourist couple had discovered a corpse, still partially frozen in the ice within a glacier area at the border between Austria (Tyrol) and Italy (South Tyrol). A chain of events followed as best described in the book by B. Fowler (2001).

A summary of scientific efforts undertaken soon after it became clear that the remains are not of an unfortunate contemporary (i.e., 20th century) hiker, provide information about this glacial mummy and the research conducted in the early years (Gaber and Künzel 1998).

The first step in the investigation of this Iceman was to find out how old he was. Acceleration mass spectrometry (AMS) was used for age determination because the smallest amount of the sample had to be used for dating. Samples were collected at the University of Innsbruck and submitted to the AMS laboratories in Oxford and Zurich (Kutschera 1994). In November 1991, a fragment of tissue and bone arrived at the laboratory at ETH Zurich. In addition, a small piece of grass was found in the Iceman's tissue and was also analyzed. The mean value of all the measurements was 4550 ± 27 BP (Bonani et al. 1994).

The unique preservation and the age of the remains (Barfield 1994) drew the attention of researchers from various disciplines. The body, which has been preserved in a specially built chamber in the dedicated museum in Bolzano, has undergone numerous scientific examinations (Zink Albert & Maixner, 2019). These and other studies of the remains and associated finds, some of them directly dated using $^{14}$C (Rom et al. 1999), resulted in an impressive list of publications (over 4.5 thousand hits in a Google Scholar search), ranging from migration (Müller et al. 2003) to diet (Dickson et al. 2000), tattoos (Samadelli et al. 2015) and animal sources in the Copper Age (O'Sullivan et al. 2016).


***Figure 1.*** *Picture of the remaining frozen tissue of the Iceman stored in a glass jar at the ETH laboratory.*

Additional radiocarbon dating that has been performed on samples associated with the find was summarized by Kutschera et al. (Kutschera and Muller 2003; Kutschera et al. 2017). Here we report radiocarbon ages on soft tissue which were measured on the rest of the material from the 1991 study (Bonani et al. 1994).

The samples from the Ötztal glacial mummy were kept in a glass jar since November 1991. In the first decade of the 21st century, school programs included special days for primary school kids. During the visits, the students were able to look at the tissue using the binocular microscope. Inspired by these visits, new analysis on the remaining material that had been stored frozen for few decades were completed as a part of a high-school project and a student internship, both completed in September 2016.

## Methods and results

First, the sample was controlled for contaminants by examination under a binocular microscope (Figure 1). In 1991, such observation allowed the determination and separation of pieces of grass mixed

https://doi.org/10.1017/RDC.2026.10194 Published online by Cambridge University Press

***Table 1.*** *a. Results of radiocarbon analysis on sub-samples selected from the frozen tissue stored at the ETH since 1991. The sample has been given a new ETH number; b. results of dating the Iceman tissue, bone and grass published by Bonani et al. (1994)*

Table 1a

| Sample number ETH | $^{14}C$ age (BP) | ±1σ | $\delta^{13}C$ (‰) | mg C | $C/N_{at}$ | %C | Comments |
|---|---|---|---|---|---|---|---|
| 68870.1 | 4534 | 22 | –20.3 | 0.99 | 3.5 | 55.3 | School project |
| 68870.2 | 4498 | 22 | –32.6 | 1.00 | 6.1 | 74.2 | School project |
| 68870.3 | 4544 | 22 | –25.6 | 1.00 | 18.9 | 85.6 | School project |
| 68870.4 | 4555 | 22 | –22.7 | 0.99 | 5.7 | 64.7 | School project |
| 68870.5 | 4550 | 25 | –27.6 | 1.00 | 63.5 | 82.5 | School project |
| 68870.6 | 4530 | 22 | –26.4 | 0.99 | 9.6 | 66.3 | School project |
| 68870.7 | 4528 | 22 | –25.6 | 1.00 | 18.5 | 77.8 | School project |
| 68870.8 | 4528 | 23 | –23.7 | 1.00 | 7.3 | 72.0 | Internship project |
| 68870.9 | 4510 | 22 | –26.1 | 1.00 | 11.8 | 78.8 | Internship project |
| 68870.10 | 4489 | 23 | –23.8 | 1.00 | 7.8 | 76.1 | Internship project |
| 68870.11 | 4515 | 23 | –25.4 | 1.00 | 11.6 | 82.7 | Internship project |
| R_Combine_ETH-68870 | 4525 | 7 | $\chi^2$-Test: df=10 T=8.5 (5% 18.3) | | | | |

Table 1b

| Sample number ETH | $^{14}C$ age (BP) | ±1σ | Material |
|---|---|---|---|
| 8345.1a | 4605 | 65 | Tissue |
| 8345.1b | 4500 | 70 | Tissue |
| 8345.1 | 4585 | 70 | Tissue |
| 8345.2 | 4515 | 70 | Tissue |
| R_Combine_ETH-8345_tissue | 4554 | 35 | $\chi^2$-Test: df=3 T=1.7 (5% 7.8) |
| 8342 | 4560 | 65 | Bone |
| 8345.2 | 4535 | 60 | Grass |
| R_Combine_all_ETH-8345&42 | 4551 | 28 | $\chi^2$-Test: df=5 T=1.8 (5% 11.1) |

into the skin and muscle tissue (Bonani et al. 1994). The standard acid–base–acid (ABA) treatment at the ETH laboratory has not changed over the decades (Hajdas 2008; Hajdas et al. 2004, 2024). Tissue samples are fragile and can easily dissolve in the base washes. Therefore, the normal ABA treatment, which involves washes in 0.5 M HCl and 0.1M NaOH, at 60 ºC for 1 hr, was monitored, and if needed, the duration of the base step was reduced to avoid loss of the sample (Hajdas et al. 2024). The graphitization of these subsamples was performed using the AGE system, which allowed for additional information of C/N ratio in the combusted samples (Hajdas et al. 2024; Nemec et al. 2010).

Results of all radiocarbon analysis are summarized in Tables 1a and 1b, together with the combined radiocarbon age of organic matter from the jar. Table 1a shows the results obtained during the student internship and school projects. The excellent agreement with the first analysis shows that frozen organic matter can be dated even after decades. The results acquired in 1991 are listed in Table 1b. Although the new data have been obtained using the MICADAS system (Synal et al. 2007) they confirm the analysis performed using the EN tandem (Bonani et al. 1994). All the data shown in Tables 1a and 1b were combined and calibrated using the OxCal 4.4 (Bronk Ramsey 2009) and the IntCal20 calibration curve (Reimer et al. 2020). The weighted mean value of 4525 ± 7 BP was obtained for the new analysis (Table 1a). All the results published by Bonani et al. (1994) were combined using R_Combine

https://doi.org/10.1017/RDC.2026.10194 Published online by Cambridge University Press

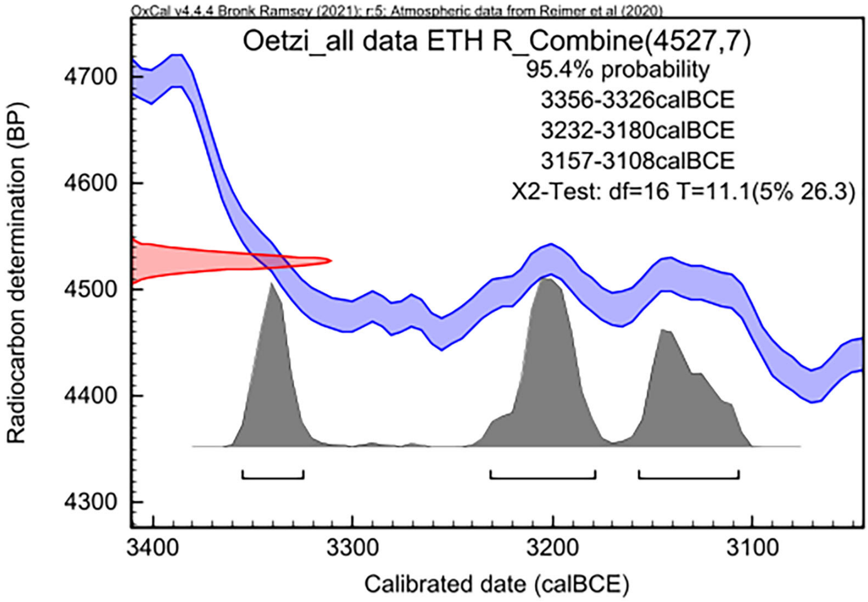


***Figure 2.*** *Calibrated radiocarbon age of the Iceman tissue, bone and grass combined using the OxCal 4.4 calibration program and the IntCal20 data.*

command of the OxCal 4.4 (Bronk Ramsey 2009) yielding weighted mean value of 4551 ± 28 BP (Table 1b). The combined age of all the data (tissue, bone and grass), measured in 1991 and in 2016 is 4527 ± 7 BP ($\chi^2$-Test; df=16 T=11.1[5% 26.3]). The calibrated age still falls into the extensive radiocarbon age plateau and results in 3 intervals 3356–3326 BCE, 3232–3180 BCE and 3157–3108 BCE (Figure 2). A possible change of $^{14}C$ calibration curve due to the high altitude of the Iceman discovery site had been investigated in 2004 (Dellinger et al. 2004) through $^{14}C$ measurements in high-elevation stone-pine tree rings, and was found to be insignificant.

## References

Barfield L (1994) The Iceman reviewed. *Antiquity* **68**, 10–26.

Bonani G, Ivy SD, Hajdas I, Niklaus TR and Suter M (1994) AMS $^{14}C$ age determinations of tissue, bone and grass samples from the Oetztal Ice Man. *Radiocarbon* **36**, 247–250.

Bronk Ramsey C (2009) Bayesian analysis of radiocarbon dates. *Radiocarbon* **51**, 337–360.

Dellinger F, Kutschera W, Nicolussi K, Schießling P, Steier P and Maria Wild E (2004) A $^{14}C$ calibration with AMS from 3500 to 3000 BC, derived from a new high-elevation stone-pine tree-ring chronology. *Radiocarbon* **46**, 969–978.

Dickson JH, Oeggl K, Holden TG, Handley LL, O'Connell TC and Preston T (2000) The omnivorous Tyrolean Iceman: Colon contents (meat, cereals, pollen, moss and whipworm) and stable isotope analyses. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* **355**, 1843–1849.

Fowler B (2001) *Iceman: Uncovering the Life and Times of a Prehistoric Man Found in an Alpine Glacier*. University of Chicago Press.

Gaber O and Künzel K-H (1998) Man from the Hauslabjoch. *Experimental Gerontology* **33**, 655–660.

Hajdas I (2008) The radiocarbon dating method and its applications in Quaternary studies. *Quaternary Science Journal - Eiszeitalter und Gegenwart* **57**, 2–24.

Hajdas I, Bonani G, Thut H, Leone G, Pfenninger R and Maden C (2004) A report on sample preparation at the ETH/PSI AMS facility in Zurich. *Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions With Materials and Atoms* **223**, 267–271.

Hajdas I, Guidobaldi G, Haghipour N and Wyss K (2024) Sample selection, characterization and choice of treatment for accurate radiocarbon analysis—Insights from the ETH Laboratory. *Radiocarbon* **66**, 1152–1165.

Kutschera W (1994) 4.4 Radiocarbon dating of the Iceman Ötzi with accelerator mass spectrometry. *Institute of Isotope Research and Nuclear Physics University of Vienna*, 1–9.

https://doi.org/10.1017/RDC.2026.10194 Published online by Cambridge University Press

Kutschera W and Muller W (2003) "Isotope language" of the Alpine Iceman investigated with AMS and MS. *Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions with Materials and Atoms* **204**, 705–719.
Kutschera W, Patzelt G, Steier P and Wild EM (2017) The Tyrolean Iceman and his glacial environment during the Holocene. *Radiocarbon* **59**, 395–405.
Müller W, Fricke H, Halliday AN, McCulloch MT and Wartho J-A (2003) Origin and migration of the Alpine Iceman. *Science* **302**, 862–866.
Nemec M, Wacker L and Gaggeler H (2010) Optimization of the graphitization process at Age-1. *Radiocarbon* **52**, 1380–1393.
O'Sullivan NJ, Teasdale MD, Mattiangeli V, Maixner F, Pinhasi R, Bradley DG and Zink A (2016) A whole mitochondria analysis of the Tyrolean Iceman's leather provides insights into the animal sources of Copper Age clothing. *Scientific Reports* **6**, 31279.
Reimer PJ, Austin WEN, Bard E, Bayliss A, Blackwell PG, Bronk Ramsey C, Butzin M, Cheng H, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Hajdas I, Heaton TJ, Hogg AG, Hughen KA, Kromer B, Manning SW, Muscheler R, Palmer JG, Pearson C, van der Plicht J, Reimer RW, Richards DA, Scott EM, Southon JR, Turney CSM, Wacker L, Adolphi F, Büntgen U, Capano M, Fahrni SM, Fogtmann-Schulz A, Friedrich R, Köhler P, Kudsk S, Miyake F, Olsen J, Reinig F, Sakamoto M, Sookdeo A and Talamo S (2020) The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* **62**, 725–757.
Rom W, Golser R, Kutschera W, Priller A, Steier P and Wild E (1999) AMS C-14 dating of equipment from the Iceman and of spruce logs from the prehistoric salt mines of Hallstatt. *Radiocarbon* **41**, 183–197.
Samadelli M, Melis M, Miccoli M, Vigl EE and Zink AR (2015) Complete mapping of the tattoos of the 5300-year-old Tyrolean Iceman. *Journal of Cultural Heritage* **16**, 753–758.
Synal HA, Stocker M and Suter M (2007) MICADAS: A new compact radiocarbon AMS system. *Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions with Materials and Atoms* **259**, 7–13.
Zink Albert R and Maixner F (2019) The current situation of the Tyrolean Iceman. *Gerontology* **65**, 699–706.

**Cite this article:** Hajdas I and Saracoğlu D (2026). Radiocarbon ages of the Iceman—Reopening a jar with the frozen tissue stored at the ETH laboratory. *Radiocarbon* **68**, 431–435. https://doi.org/10.1017/RDC.2026.10194