

# (Digital) Stratigraphy and Other Chronological Dating Techniques

Comparing Chronological Dating Methods in Archaeology to those in Digital Forensics

Lisa Marie Dreier (lisa.dreier@fau.de)

One of the main questions in criminal investigations—and thus in digital forensics—is "When did the event happen?". But this is one of the core questions for other sciences as well, e.g. archaeology. There, two types of "chronological dating" are typically distinguished:

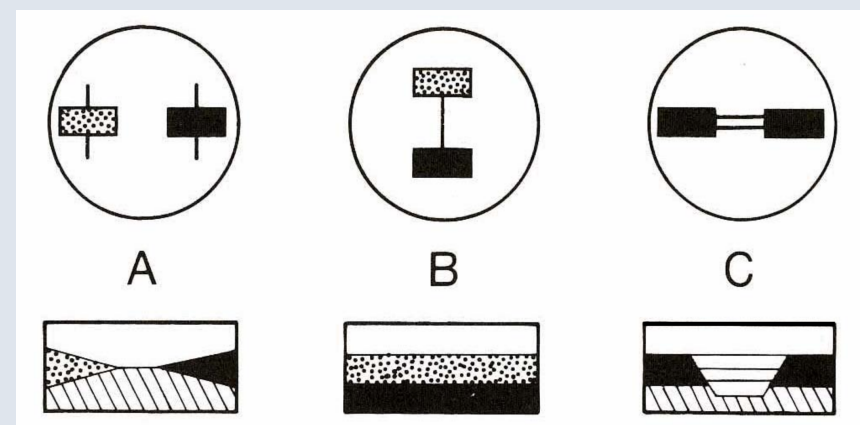
- *Absolute Dating*: Determining the age of an event/action/etc. in numbers
- *Relative Dating*: Determining the chronological order of events/actions/etc.

This poster presents concepts of archaeological dating methods and relates them to corresponding methods in digital forensics. The list of dating methods and concepts does *not* claim to be complete. But it is intended as a starting point for a discussion about chronological dating in digital forensics!

## Base Concepts of Chronological Reasoning

Relative Dating is typically based on observation of chronological relationships between events or periods, e.g.

- *terminus post quem*: event *a* (minting of coin) cannot have happened before event *b* (accession of emperor) because emperor's face is minted onto the coin
- *terminus ante quem*: event *a* (building of house) must have happened before event *b* (eruption of Vesuv), because the building was found covered by the eruption's ash
- "in same epoch": two objects share characteristics of the same epoch

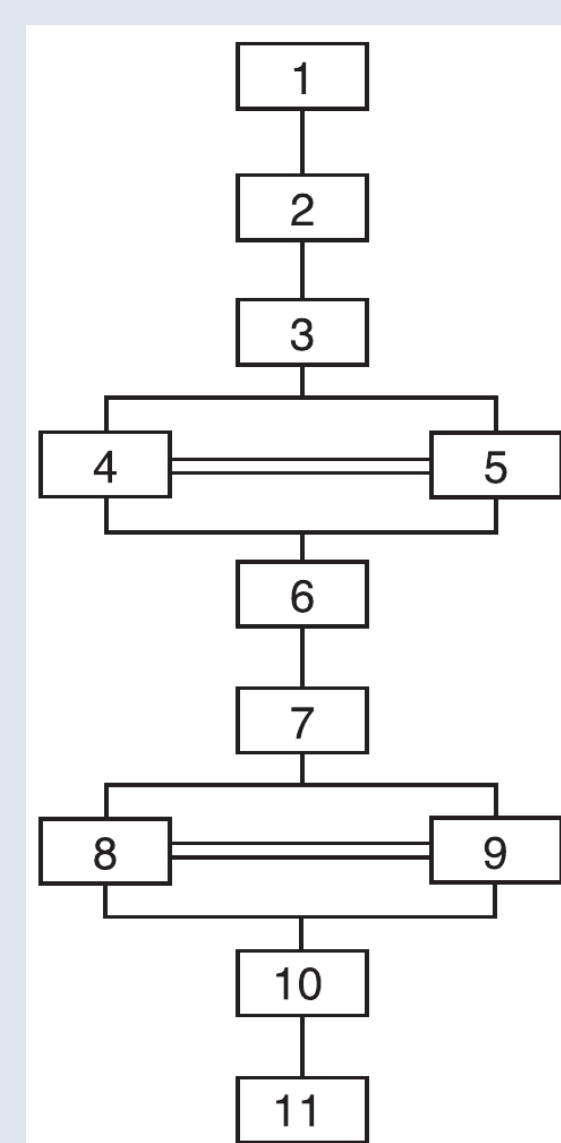


Possible chronological relationships: A = unrelated, B = successively, C = simultaneously [8, p. 36, fig. 9]

Such ordering is often inferred quite informally, even though there do exist formalizations for certain methods, e.g. the Harris Matrix for stratigraphy [8]: There, every stratum is displayed as a node with connections to other nodes expressing their chronological ordering:

- vertical connection: the upper stratum is (directly) later than the lower one
- horizontal double line: two strata are equal in age

This way, archaeologists create a "web" of events. Nevertheless, handling estimations and uncertainty of chronological ordering (with this approach) is still an issue addressed by recent research [3]



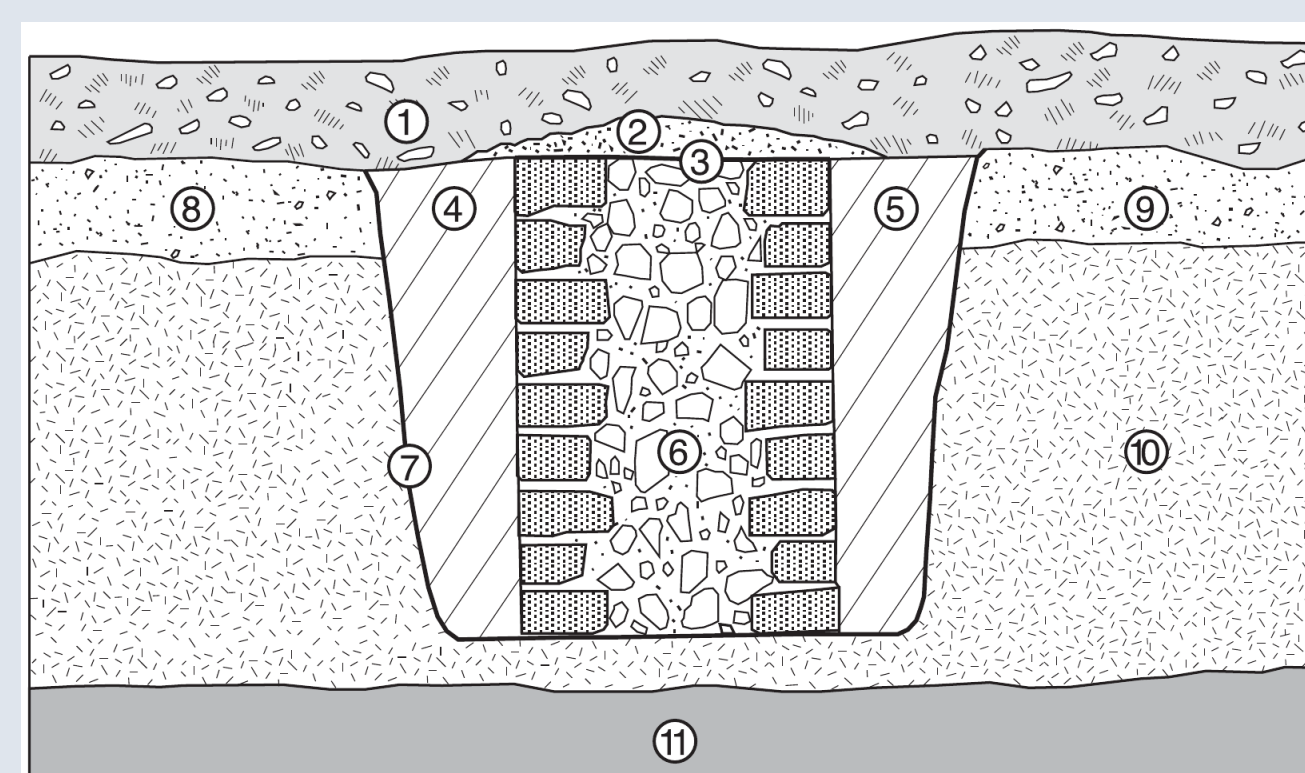
Exemplary Harris Matrix [6, p. 176, fig. 37C], corresponding to schematic view below

## Similar dating concepts used in digital forensics:

- Hypertimeline [5]
- Time Anchors [13]
- Do you know any other methods?

## Stratigraphy

Stratigraphy is a method to determine temporal relationships between two strata, which are sediment layers or interfaces between them [8]. It is based on interpreting the relative positioning between strata using certain laws, e.g. the "law of superposition" stating that the upper layer of two adjacent strata typically was formed later than the lower one. These laws are related to the creation process of the sequence of strata.



Schematic view of a section through an archaeological site. Corresponds to Harris Matrix above [6, p. 176, fig. 37A]

## Similar dating concepts used in digital forensics:

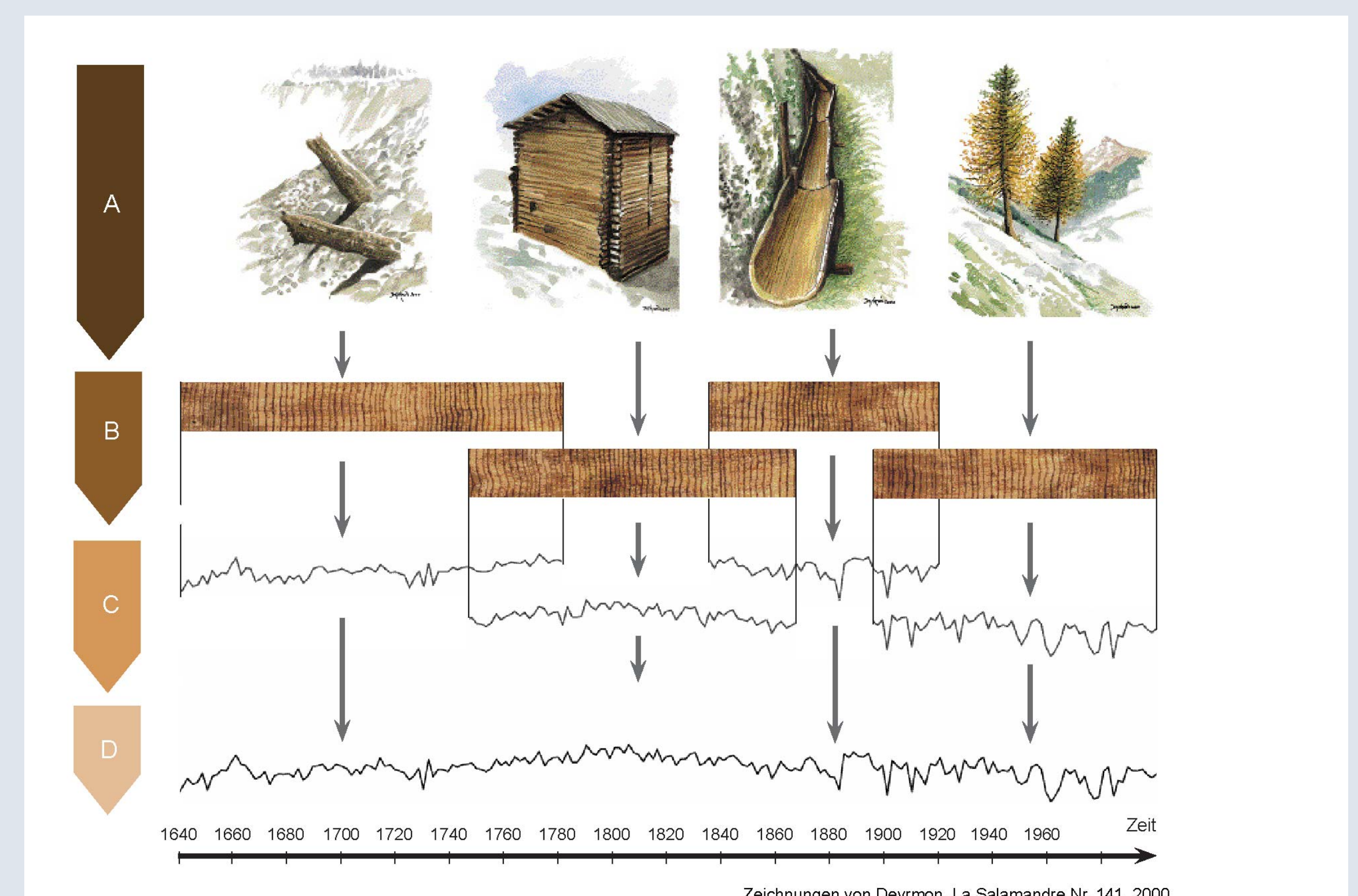
- File System Driver Analysis [2, 11]
- Determine a file's original file system on a used USB drive based on the file system allocation strategy [12]
- Inference System for the order in which the NTFS entries were created based on a first-fit allocation strategy [15]
- Reconstruction of actions based on how timestamps were changed [1]
- Do you know any other methods?

## Dendrochronology

Trees form tree rings, which can be seen in a section of the tree and vary in thickness over time due to climatical conditions [4]. Based on shared tree ring patterns, various pieces of wood from overlapping time periods can be used to create a *master chronology*. It can then be used to match tree ring patterns of additional pieces of wood onto it.



Tree rings of a bald cypress [10]



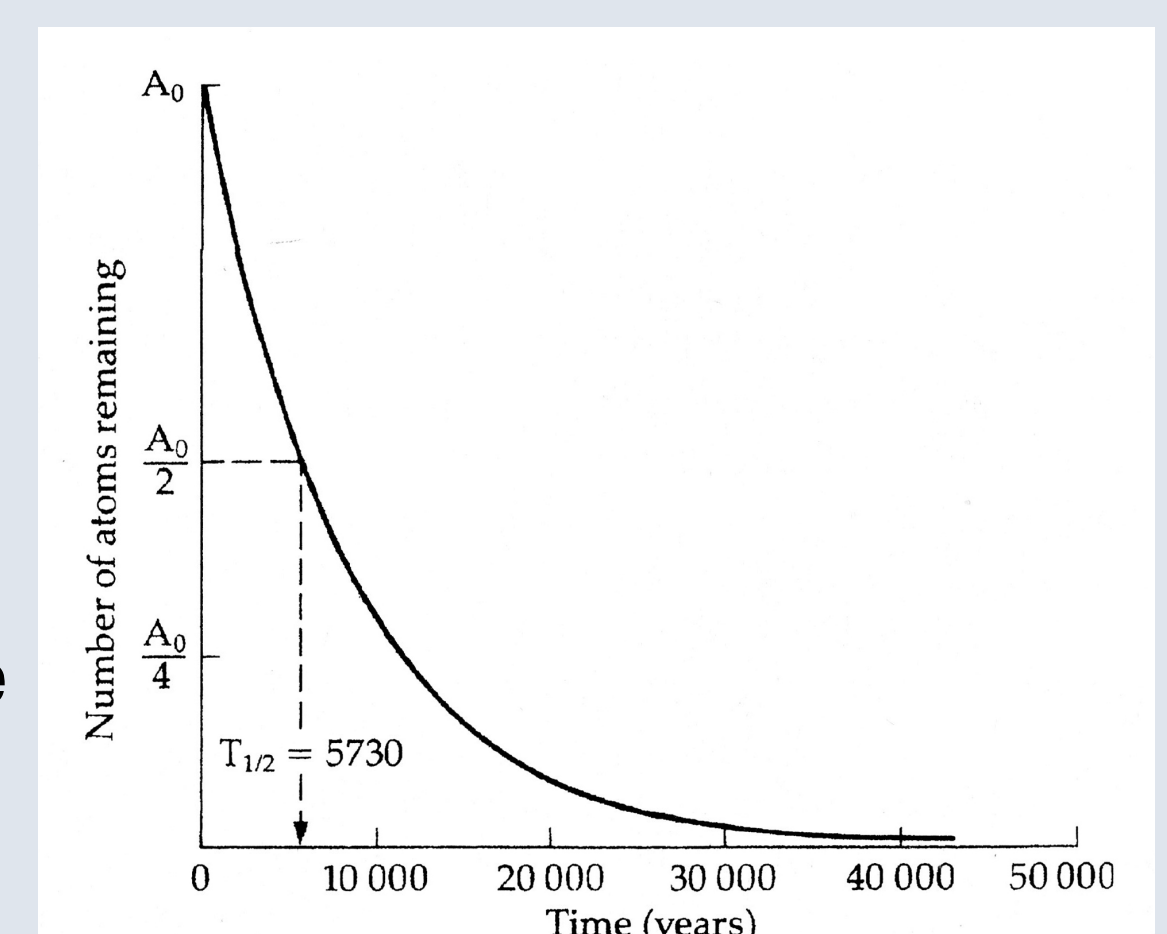
Crossdating trees yields a master chronology of tree rings [7, fig. 1]

## Similar dating concepts used in digital forensics:

- Electric Network Frequency (ENF) Criterion [9]
- Unclear whether there are any more. Do you know any other method?

## Radiocarbon Dating

$^{14}\text{C}$  is a non-stable isotope of carbon, which not only decays, but is also constantly being created in the atmosphere and passed to all living organisms. But with death, the supply of newly created  $^{14}\text{C}$  stops, so the previously constant level of  $^{14}\text{C}$  starts to decline. Thus, measuring the level of  $^{14}\text{C}$  present in a dead organism permits the start of the decay (and thus the time of death) to be calculated.



Exponential decay curve of  $^{14}\text{C}$  [14, p. 19, fig. 2.1]

## Similar dating concepts used in digital forensics: Unclear. Do you know any?

## References

- [1] J. Bouma, H. Jonker, V. van der Meer, and E. V. D. Aker. Reconstructing timelines: From NTFS timestamps to file histories. In *Proceedings of the 18th International Conference on Availability, Reliability and Security, ARES 2023, Benevento, Italy, 29 August 2023 - 1 September 2023*, pages 154:1–154:9. ACM, 2023.
- [2] E. Casey. Digital stratigraphy: contextual analysis of file system traces in forensic science. *Journal of forensic sciences*, 63(5):1383–1391, 2018.
- [3] B. Desachy. From observed successions to quantified time: formalizing the basic steps of chronological reasoning. *Acta Imeko*, 5(2):4, 2016.
- [4] A. E. Douglass. *A study of the Annual Rings of Trees in Relation to Climate and Solar Activity*, volume 1 of *Climatic cycles and tree-growth*. Washington Carnegie Institution of Washington, 1919.
- [5] L. M. Dreier, C. Vanini, C. J. Hargreaves, F. Breilinger, and F. C. Freiling. Beyond timestamps: Integrating implicit timing information into digital forensic timelines. *Forensic Sci. Int. Digit. Investig.*, 49:301755, 2024.
- [6] M. K. Eggert. *Prähistorische Archäologie: Konzepte-Methoden-Theorien*. utb GmbH, 2024.
- [7] ETH Zürich. Kreuzdatierung, 2025. <https://fe.ethz.ch/forschung/dendrochronology-and-phenology/jahring-labor/kreuzdatierung.html> [accessed March 09, 2025].
- [8] E. C. Harris. *Principles of archaeological stratigraphy*. Academic Press, 1987.
- [9] M. Huijbregtse and Z. J. M. H. Geradts. Using the ENF criterion for determining the time of recording of short digital audio recordings. In Z. J. M. H. Geradts, K. Franke, and C. J. Veenman, editors, *Computational Forensics, Third International Workshop, IWCF 2009, The Hague, The Netherlands, August 13-14, 2009. Proceedings*, volume 5718 of *Lecture Notes in Computer Science*, pages 116–124. Springer, 2009.
- [10] James St. John. Tree rings in taxodium distichum wood (bald cypress) 2, 2019. <https://commons.wikimedia.org/w/index.php?curid=83884071> [accessed March 09, 2025].
- [11] M. Karresand. *Digital Forensic Usage of the Inherent Structures in NTFS*. PhD thesis, Norwegian University of Science and Technology, Trondheim, Norway, 2023.
- [12] J. Schneider, M. Eichhorn, L. M. Dreier, and C. Hargreaves. Applying digital stratigraphy to the problem of recycled storage media. *Forensic Sci. Int. Digit. Investig.*, 49:301761, 2024.
- [13] C. Vanini, C. J. Hargreaves, H. van Beek, and F. Breilinger. Was the clock correct? exploring timestamp interpretation through time anchors for digital forensic event reconstruction. *Forensic Sci. Int. Digit. Investig.*, 49:301759, 2024.
- [14] M. Walker. *Quaternary dating methods*. John Wiley & Sons, 2013.
- [15] S. Y. Willassen. Finding evidence of antedating in digital investigations. In *Proceedings of the The Third International Conference on Availability, Reliability and Security, ARES 2008, March 4-7, 2008, Technical University of Catalonia, Barcelona, Spain*, pages 26–32. IEEE Computer Society, 2008.