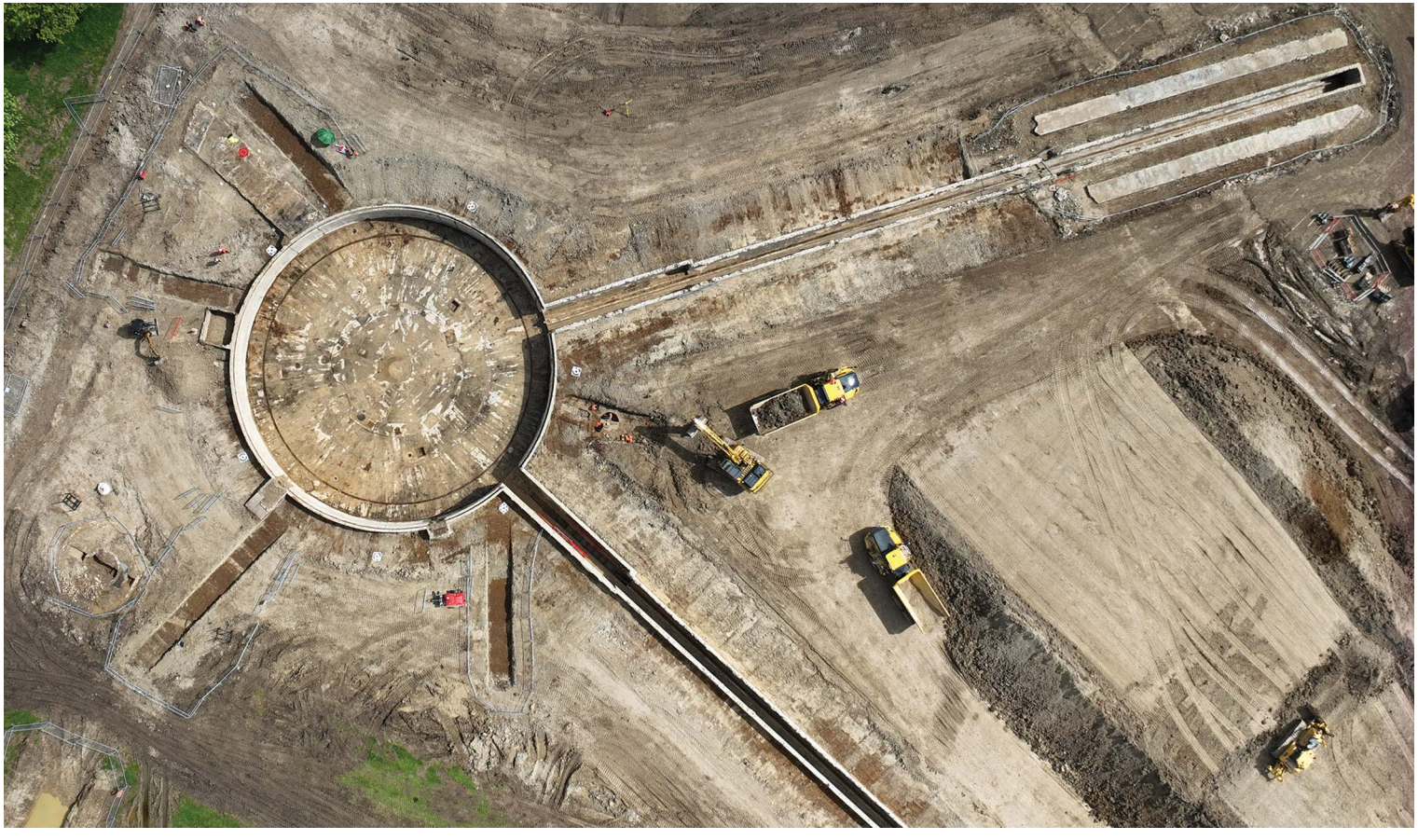

Frontispiece 1. Aerial photograph of the excavation of a Second World War experimental catapult designed to launch bomber aircraft, at Harwell, Oxfordshire, England. The catapult, constructed between 1938 and 1940, was intended to allow planes to take off using shorter runways and less fuel. The prototype comprised a 30m-wide pit with a turntable to align planes on one of two concrete runways, each just 82m long. A towing hook attached to a pneumatic ram was intended to launch the planes into the air but design problems meant the RAE Mark III catapult was never used and the site was abandoned by 1941. A 3D model is available at: https://skfb.ly/oM7Wr. Photograph © MOLA.

Frontispiece 2. A reconstruction of Tenochtitlan, the capital of the Aztec (Mexica) Empire, as it may have looked in AD 1518 when the city had 200 000 or more inhabitants. Drawing on documentary sources, such as codices written shortly after the Spanish conquest of 1519, the image is based on a 3D model created using open-source software including Blender, Gimp and Darktable. Starting with the terrain, the model integrates known points such as the Templo Mayor and uses a rules-based method to populate the rest of the landscape. Further images and comparisons with present-day Mexico City are available at: https://tenochtitlan.thomaskole.nl with text in English, Spanish and Central Nahuatl. Image © Thomas Kole.

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GUEST EDITORIAL

Archaeology after the loss of innocence

This year marks the 50th anniversary of the publication of David Clarke's much-cited *Antiquity* article 'Archaeology: the loss of innocence'.[1] While it may not be as renowned today as it once was—especially among those who, like me, were born after its publication—Clarke's portrait of the discipline still resonates. Here, I discuss some of the ways in which the article continues to be relevant before going on to describe how recent developments that Clarke foresaw in his essay have led to advances in archaeological methods and theory through an approach called macroarchaeology.

Clarke's article described a developing discipline characterised by growth spurts and all their associated pains and angst. He characterises this development as a series of transitions from consciousness to self-consciousness and, finally, to critical self-consciousness. The last transition is marked by the development of a meta-understanding of the discipline and its epistemological foundations, and it is a transition whose symptoms persist. Not least, disciplinary sectarianism was anything but "temporary", as Clarke had optimistically hoped.[2] The bruising battles of the post-processual archaeology era were never fully resolved. Rather, they gave rise to a truce—live and let live—with no apparent way out; the discipline remains as divided as ever.

In addition, archaeologists continue to draw from a stock of explanatory models that are often at odds with the nature of archaeological data. Clarke's criticism remains valid: "To interpret the French Mousterian sequence, of more than 30,000 years duration, in terms of the acrobatic manoeuvrings of five typological tribes is tantamount to an attempt to explain the Vietnam war in terms of electron displacements."[3] Wrong hierarchical scale, wrong spatial scale, and wrong temporal scale. Archaeologists often interpret the archaeological record in terms of processes borrowed from other disciplines that operate over short time scales of a decade or less.[4] For various reasons, historical and other, archaeologists tend to view themselves as ethnographers of the past. We try to translate a heavily fragmented, incomplete, mixed and distorted record into ethnographic vignettes recognisable to a cultural anthropologist. Like ethnographers, our primary interest often lies in individuals and the processes that

[1] Clarke, D. 1973. Archaeology: the loss of innocence. *Antiquity* 47: 6–18. https://doi.org/10.1017/S0003598X0003461X
[2] Clarke, D. 1973, p.11.
[3] Clarke, D. 1973, p.10.
[4] Bailey, G.N. 1981. Concepts, time-scales and explanations in economic prehistory, in A. Sheridan & G.N. Bailey (ed.) *Economic archaeology: towards an integration of ecological and social approaches* (British Archaeological Reports International series 96): 99–117. Oxford: BAR; Perreault, C. 2019. *The quality of the archaeological record*. Chicago (IL): University of Chicago Press. https://doi.org/10.7208/chicago/9780226631011.001.0001

influence them, whether agentic, ecological, economic, social or ideological and that thus operate over time scales shorter than that of a human lifespan. Since these processes cannot be observed directly in the record, they must be inferred indirectly using unverified—and unverifiable—proxies. For this research strategy to work, archaeologists must use 'the test of consistency' to support their interpretations, that is, interpretations are accepted when they can be made consistent with the data.[5] However, consistency is not enough to make claims about the past. Given the information-loss processes that act on archaeological data, many confounding factors cannot be controlled and can create false positive or false negative results. The more significant the discrepancy between the scale of the data and the scale at which the processes of interest operate, the more acute this problem of underdetermination becomes.

Clarke argued that for the field to mature and resolve these issues, it must answer fundamental, if sometimes "demoralising",[6] questions such as how we know what we appear to know reliably. The first step in that direction, he contended, must be a "comprehensive archaeological general theory" that links "predepositional, depositional, postdepositional, retrieval, analytical and interpretive models".[7] Building upon previous efforts to address Clarke's challenge (discussed, for example by Schiffer and Bailey),[8] this general theory is effectively what I set out in the book *The quality of the archaeological record*. There, I estimate the expected distribution of resolution, interval scale and richness of archaeological data and describe how this quality constrains what we can and cannot study. Based on this, I argue for a recalibration of the research questions of the wider discipline.

If archaeologists want to produce reliable knowledge, we must scrap the consistency test and replace it with a 'smoking gun' approach. As a discipline, we must find evidence that is not just consistent with a hypothesis, but that also discriminates between plausible competing theories. The bar should be set high: a question is only ever answered if supported by evidence *beyond a reasonable doubt*. Given the incomplete nature of the archaeological record, smoking guns for many, if not most, ethnographic-level explanations will likely never be found. Hence, we need to focus on those areas where archaeology can make strong knowledge claims.

Three misunderstandings of this argument inhibit a transition to a critical self-consciousness by a broader part of the archaeological community. First, a 'smoking gun' does not mean that a singular find can resolve the complex questions that we ask. Rather, it is a metaphor that refers to any evidence(s) that can discriminate unambiguously between competing hypotheses. This can include a statistical model or a dataset with thousands of data points. The concept of the smoking gun is helpful because it captures how the historical sciences work: first, traces must be found in the field—they cannot be manufactured in a laboratory; and second, these traces must discriminate between competing hypotheses.

[5] Perreault, C. 2019, pp.8–14.
[6] Clarke, D. 1973, p.7.
[7] Clarke, D. 1973, p.16.
[8] Schiffer, M.B. 1987. *Formation processes of the archaeological record*. New York: Academic Press; Bailey, G. 2007. Time perspectives, palimpsests and the archaeology of time. *Journal of Anthropological Archaeology* 26: 198–223. https://doi.org/10.1016/j.jaa.2006.08.002

The second misunderstanding is that 'beyond a reasonable doubt' is, to some, an unrealistic bar to pass and one that does not capture how science works. I disagree. Beyond a reasonable doubt does not mean something has been 'proven' or will not be revised in the future. Instead, it means any reasonable person who understands the competing hypotheses would reach the same conclusion when presented with the data. Archaeology should aim for such strong inferences. We have already produced results that are beyond a reasonable doubt. That agriculture in Europe originates from South-west Asia or that state societies emerged only during the Holocene are overwhelmingly supported by empirical evidence, even if they are, and always will be, hypotheses susceptible to revision. These strong inferences are victims of their own success: they are so well supported that they have faded into background knowledge and are taken for granted.

The final misunderstanding preventing a transition to critical self-consciousness is that some archaeologists believe it is by asking unanswerable questions that we make progress. Hard questions, the argument goes, push us to rack our brains, develop new methods, and expand the range of traces we can recover in the field. This is overstated; advances in methods and techniques often come from outside the discipline and are made independently of our research interests. The danger in centring our research programmes on questions that we know, *a priori*, cannot be answered beyond a reasonable doubt is that we end up assuming the very thing we set out to find, settling on an interpretation, despite lacking a smoking gun, merely because it is consistent with the data. This will never be productive. No one would want a judicial system that found people guilty and sent them to prison without proper evidence because, perhaps, such evidence might be found in some distant future. Likewise, no one would argue that such a judicial system is justified because it could someday lead to advances in forensic techniques. These are not insurmountable problems, and seeking to settle unlikely questions is fine if one accepts that questions remain unanswered until a smoking gun is found, if ever. But would it not be better to return to these questions *after* the methods to answer them have been developed?

One of the central claims in *The quality of the archaeological record* is that archaeologists need to focus on those questions that can realistically be expected to be answered *beyond a reasonable doubt*. Two kinds of research agenda are commensurate with the archaeological record's quality and amenable to a search for smoking guns: cultural history and macroarchaeology.

Cultural history here does not mean the late-nineteenth-century theory that emphasised the history of ethnic groups and 'cultures' (and which was often instrumentalised for nationalistic political agendas). Instead, it refers to making inferences about the distributions and boundaries of cultural elements in time and space, determining their relatedness, sources and trajectories, and constructing narratives of the events that shaped these distributions. For instance, how did bow-and-arrow technology diffuse across Eurasia, or how did basketry technology in coastal Peru change over millennia? When were pigs first domesticated, and how quickly did the practice spread? Were the first full-time residents of the Tibetan Plateau foragers or farmers? Cultural history thus entails more than describing physical finds and situating them in time and space. It stands somewhere between dating phenomena and constructing archaeological chronologies and trying to explain them in functional terms. The

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questions of cultural history are certainly of a type that we can answer beyond a reasonable doubt and they account for much of the epistemologically valid work the field has produced.

Similarly, macroarchaeology is the task of detecting patterns and processes that are not visible at the individual level but only in the aggregate, over thousands of years and across thousands of kilometres. It demands a particular research strategy that includes:

1. A focused set of research questions. Macroarchaeology is concerned with characterising statistical patterns of rates of cultural change, abundance, distribution and diversity, and explaining these patterns in terms of macroscale drivers such as climate change and biogeography.
2. A programme centred on archaeological entities. It is material culture-centric, not individual-, behavioural, or socio-centric. Its primary interest is in archaeological entities and their distributions in time and space, not social, economic and ideological processes in the past, at least never directly. This is what Clarke describes in *Analytical archaeology*:[9] "archaeology as archaeology" as opposed to "archaeology as anthropology".[10]
3. An interest in the *general* properties of archaeological entities. These entities are not technology- or culture-specific and include temporal ranges, geographical ranges, diversity, efficiency and complexity. These variables have the advantage of being observable directly in the archaeological record.
4. Macroscale databases with broad temporal *and* spatial scope. Macroscale patterns and processes are only detectable over vast amounts of time and space. Macroscale databases also reduce the chances of observing false patterns and help reduce issues of underdetermination.[11]

Over the past few years, a small group of archaeologists has been quietly laying the foundations for the study of macroscale phenomena in the archaeological record. The first item on the list above will naturally emerge from any programme combining the three others. Here, I discuss advances made on items #2 and #4. Some of these advances involve general archaeological properties (#3), but much work remains to be done on this front.

Among the most natural archaeological entities that are amenable to macroarchaeological research are artefact typologies and other cultural taxonomies.[12] These have recently been the subject of renewed interest, including a debate article in this journal with responses.[13] Of particular interest are the circumstances under which cultural taxonomies capture empirical

[9] Clarke, D. 1968. *Analytical archaeology*. London: Methuen.
[10] Shennan, S. 1989. Archaeology as archaeology or as anthropology? Clarke's *Analytical archaeology* and the Binfords' *New perspective in archaeology* 21 years on. *Antiquity* 63: 831–35. https://doi.org/10.1017/S0003598X00076985
[11] Perreault, C. 2019, pp.181–88.
[12] Clarke, D. 1968. *Analytical archaeology*. London: Methuen.
[13] Reynolds, N. & F. Riede. 2019. House of cards: cultural taxonomy and the study of the European Upper Palaeolithic. *Antiquity* 93: 1350–58. https://doi.org/10.15184/aqy.2019.49

realities.[14] Recent statistical and computing methods are also being leveraged to create robust cultural taxonomies.[15] This is foundational work for the construction of a macroarchaeology programme.

Another crucial step recently made towards macroarchaeology has been the advent of macroscale databases. Clarke foresaw this development, and he noted the "sense-extending" capacity of "computer methodology", which, like a telescope, allows us to scrutinise massive ensembles over a vast scale.[16] Macroscale databases let us look at galaxies of cultural data. A recent crop of databases, listed in Table 1, are differentiated from previous regional or national archaeological datasets by virtue of their scope, encompassing thousands of years and vast distances, sometimes even multiple continents.

These efforts have borne fruit and led to the discovery of several macroarchaeological patterns and processes, including:

- the temporal frequency distributions of radiocarbon ages of European Neolithic cultures are normally distributed;[17]
- increases in technological efficiency in stone tool technology may have been accompanied by an increased variation of the efficiency distribution;[18]
- projectile point diversity in Late Pleistocene North America increased exponentially over time, while spatial extent decreased exponentially, consistent with an evolutionary branching process;[19]

[14] For example, Clark, G.A. & J. Riel-Salvatore. 2006. Observations on systematics in Paleolithic archaeology, in E. Hovers & S.L. Kuhn (ed.) *Transitions before the transition: Evolution and stability in the Middle Paleolithic and Middle Stone Age*: 29–56. New York: Springer. https://doi.org/10.1007/0-387-24661-4_3; Serwatka, K. & F. Riede. 2016. 2D geometric morphometric analysis casts doubt on the validity of large tanged points as cultural markers in the European Final Palaeolithic. *Journal of Archaeological Science: Reports* 9: 150–59. https://doi.org/10.1016/j.jasrep.2016.07.018; MacLeod, N. 2018. The quantitative assessment of archaeological artifact groups: beyond geometric morphometrics. *Quaternary Science Reviews* 201: 319–48. https://doi.org/10.1016/j.quascirev.2018.08.024 Ivanovaitė, L., K. Serwatka, C.S. Hoggard, F. Sauer & F. Riede. 2020. All these fantastic cultures? Research history and regionalization in the Late Palaeolithic tanged point cultures of Eastern Europe. *European Journal of Archaeology* 23: 162–85. https://doi.org/10.1017/eaa.2019.59; Barton, C.M. & G.A. Clark. 2021. From artifacts to cultures: technology, society, and knowledge in the Upper Paleolithic. *Journal of Paleolithic Archaeology* 4: 16. https://doi.org/10.1007/s41982-021-00091-8; Matzig, D.N., S.T. Hussain & F. Riede. 2021. Design space constraints and the cultural taxonomy of European Final Palaeolithic large tanged points: a comparison of typological, landmark-based and whole-outline geometric morphometric approaches. *Journal of Paleolithic Archaeology* 4: 27. https://doi.org/10.1007/s41982-021-00097-2

[15] Matzig, D.N., S.T. Hussain & F. Riede. 2021. Design space constraints and the cultural taxonomy of European Final Palaeolithic large tanged points: a comparison of typological, landmark-based and whole-outline geometric morphometric approaches. *Journal of Paleolithic Archaeology* 4: 27. https://doi.org/10.1007/s41982-021-00097-2

[16] Clarke, D. 1973, p.9.

[17] Manning, K., A. Timpson, S. Colledge, E. Crema, K. Edinborough, T. Kerig & S. Shennan. 2014. The chronology of culture: a comparative assessment of European Neolithic dating approaches. *Antiquity* 88: 1065–80. https://doi.org/10.1017/S0003598X00115327

[18] Režek, Ž., H.L. Dibble, S.P. McPherron, D.R. Braun & S.C. Lin. 2018. Two million years of flaking stone and the evolutionary efficiency of stone tool technology. *Nature Ecology and Evolution* 2: 628–33. https://doi.org/10.1038/s41559-018-0488-4

[19] Hamilton, M.J., B. Buchanan & R.S. Walker. 2019. Spatiotemporal diversification of projectile point types in western North America over 13,000 years. *Journal of Archaeological Science: Reports* 24: 486–95. https://doi.org/10.1016/j.jasrep.2019.01.029

- the spatial area of point types is wider than those of tribal region and resemble that of large language groupings;[20]
- cultural evolution of Arctic technology acted on a species-like scale, with traditions forming integrated and isolated clades that show little evidence for blending;[21]
- the frequency distribution of settlement persistence is heavy-tailed, possibly log-normal or power-law;[22]
- the exponent of the scaling relation between population and settlement area varies between 2/3 and 5/6.[23]

Examples of macroscale processes include:

- climatic drivers, especially high-amplitude variability in precipitation, leading to continental-scale demographic downturns;[24]
- that the persistence of settlements is positively correlated with environmental productivity;[25]
- that significantly wetter climatic conditions are correlated to an increase in the frequency of radiocarbon dates;[26]
- that the advent of complex societies marked a decoupling of climate and demography;[27]
- and that booms-and-busts, not steady population growth, followed the introduction of agriculture in Europe.[28]

[20] Buchanan, B., M.J. Hamilton, J.C. Hartley & S.L. Kuhn. 2019. Investigating the scale of prehistoric social networks using culture, language, and point types in western North America. *Archaeology and Anthropological Sciences* 11: 199–207. https://doi.org/10.1007/s12520-017-0537-y

[21] Prentiss, A.M., M.J. Walsh, E. Gjesfjeld, M. Denis & T.A. Foor. 2022. Cultural macroevolution in the middle to late Holocene Arctic of east Siberia and North America. *Journal of Anthropological Archaeology* 65: 101388. https://doi.org/10.1016/j.jaa.2021.101388

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[23] Ortman, S.G., J. Lobo & M.E. Smith. 2020. Cities: complexity, theory and history. *PLoS ONE* 15: e0243621. https://doi.org/10.1371/journal.pone.0243621

[24] Riris, P. & M. Arroyo-Kalin. 2019. Widespread population decline in South America correlates with mid-Holocene climate change. *Scientific Reports* 9: 6850. https://doi.org/10.1038/s41598-019-43086-w

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[27] Palmisano, A., D. Lawrence, M.W. De Gruchy, A. Bevan & S. Shennan. 2021.

[28] Shennan, S., S.S. Downey, A. Timpson, K. Edinborough, S. Colledge, T. Kerig, K. Manning & M.G. Thomas. 2013. Regional population collapse followed initial agriculture booms in mid-Holocene Europe. *Nature Communications* 4: 2486. https://doi.org/10.1038/ncomms3486

It should be emphasised that macroarchaeology is not the same as cultural macroevolution archaeology. The former follows from the nature of the archaeological record. The latter, in contrast, derives from a theory of cultural inheritance and the multi-scalar, hierarchical properties of evolution. As Prentiss notes, cultural macroevolution archaeology existed before my book with its macroarchaeology programme was published.[29] However, cultural macroevolutionary archaeology has tended to emphasise the hierarchical level of analysis and not the scope of its sampling universe.[30] As a result, most examples of cultural macroevolution archaeology are small regional studies with a scope too small to count as macroarchaeology, as defined here. That said, I believe macroarchaeology and cultural macroevolutionary archaeology are related, and I can see how one naturally leads to the other. Moreover, the tent of macroarchaeology is broad and ought to be able to accommodate those who have been critical of cultural macroevolutionary archaeology. After all, one does not need to be an evolutionist to appreciate the archaeological record's limitations and the underdetermination crisis that plagues the field.

Clarke began his article by stating that the loss of disciplinary innocence may come at a high price but also with a substantial prize.[31] This prize, I believe, includes the discovery of macroscale patterns and processes. But it has taken five decades for the macroscale databases that Clarke foresaw to become available. My book explores in detail the historical, conceptual and psychological reasons that explain this delay.[32] In addition, there were practical and technological reasons for this slow progress. The digital revolution and the internet, for instance, have undoubtedly made the construction of macroscale databases easier, as has the creation of digital data repositories, such as the Digital Archaeological Record (tDAR.org) and ARIADNE (portal.ariadne-infrastructure.eu), organisations such as the Coalition for Archaeological Synthesis (www.archsynth.org) and the *Journal of Open Archaeological Data*. With the developments outlined here, macroarchaeology may lead to a unified research programme as it de-emphasises the numerous, and often underdetermined, processes that operate over time scales of decades or less. In doing so, macroarchaeology may decrease the sectarianism that has prevailed ever since Clarke published his article 50 years ago. That is my hope for the archaeology of the next five decades.

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[29] Prentiss, A.M. 2020. Review of *The quality of the archaeological record* by Charles Perreault. *American Antiquity* 85: 392–3. https://doi.org/10.1017/aaq.2020.3

[30] According, for example, to O'Brien, M.J. & R.L. Lyman. 2000. *Applying evolutionary archaeology*. New York: Kluwer Academic/Plenum. https://doi.org/10.1007/b100324 and Prentiss, A.M., I. Kuijt & J.C. Chatters (ed.) 2009. *Macroevolution in human prehistory*. New York: Springer. https://doi.org/10.1007/978-1-4419-0682-3

[31] Clarke, D. 1973, p.6.

[32] Perreault, C. 2019.

Table 1. Examples of macroscale databases. For details of Sources, see References section.

Database	Nature of data	Spatial Scope	Temporal Scope	Size	Source
1511NAC	Lithic toolkit composition, 2D shapes, cultural taxonomy	Europe	15 000–11 000 years	86 taxonomic units, >5000 2D shapes	Hussain *et al.* 2023
AfriArch Isotopic Database	Bioarchaeological stable isotope, radiocarbon ages	Africa	12 000 BC–AD 2020	5568 entries	Goldstein *et al.* 2022
ArkeOpen	Site description, technology, material, landscape	Global, but mainly Europe	5000 ± 2000 BC	>20 000 sites	ArkeOpen n.d.
Cultural Evolution of Neolithic Europe (EUROVOL)	Site age, faunal and botanical content	Central & NW Europe	8000–4000 BP	4457 sites, 14 131 14C ages, >8300 archaeobotanical record; >3m fauna counts	Colledge 2016, Manning 2016, Manning *et al.* 2016
CyberSW	Architecture, material and artefact classes, occupation duration	US SW & NW Mexico	AD 200–1900	>23 000 sites; >30m typed ceramics, >18 000 sourced obsidian objects	Mills *et al.* 2020
Digital Index of North American Archaeology (DINAA)	Site description, artefact, fauna	North America	15 000 BC–AD 2000	>800 000 sites	Anderson *et al.* 2019
Holocene Arctic technologies	Characters in harpoon heads, architecture, lithics	North America, E Siberia	~4200 ± 750 uncal BP	31 sites	Prentiss *et al.* 2022
Near East Radiocarbon Dates (NERD)	Radiocarbon ages	Near East, ~5.9m km^2	15 000 BC–AD 2000	11 027 14C	Palmisano *et al.* 2022

(*Continued*)

Table 1. (Continued)

Database	Nature of data	Spatial Scope	Temporal Scope	Size	Source
PaleoAsiaDB	Site description, lithic technological modes	Asia	200 000–20 000 years	7639 cultural layers from 3322 sites	Nishiaki & Kondo 2023
Pan-American Ceramics Project (PACP)	Ceramics production and function: wares, types, petro-fabrics	North, Central & South America	Last 7500 years	865 vessels, 100 wares, 271 types (this is a growing crowd-sourced resource)	Pan-American Ceramics Project n.d.
People3000 Archaeological Radiocarbon Database (P3k14c)	Radiocarbon ages	Global		>180 000 14C dates	Bird *et al.* 2022
Procedural units complexity	Presence/absence of procedural units	Global	3m years	56 tool-making sequences	Paige & Perreault, in press
Projectile point typologies	Point types distribution area, longevity	W North America	13 000 BP to present	93 types	Hamilton *et al.* 2019. Justice 1987, 2002a & b
ROCEEH Out of Africa Database (ROAD)	Sites description, types of cultural remains, dates, stratigraphy	Africa & Eurasia	3m–20 000 BP	13 000 assemblages	Kandal *et al.* 2023
Settlement persistence	Occupation duration	Global	4000 BC–AD 1800	15 414 locations	Crawford *et al.* 2023
Social Reactors Project	Settlement areas, population size	Global	6000 BC–AD 1520	5575 sites	Ortman *et al.* 2020, and tDAR project id 392021
Stone tool efficiency	Flake tool efficiency	Africa, W Europe, SW Asia	2m years	18 000 flakes from 81 assemblages	Režek *et al.* 2018

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