Sjoerd J. Kluiving and Arthur Hamel

How Can Archaeology Help Us Unravel the Anthropocene?

Both scholars and the public have long argued over *when* the Anthropocene began, and these discussions have almost exclusively focused on the impacts of human activity on the planet. As geoarchaeologists, we consider the far more interesting question to be *why* it began. What were the underlying causes of the changes that resulted in this new epoch, and how can we trace them? The answer lies in humans' relationship with the environment—by looking at changes in human behavior over time we find a compelling explanation for how and why the Anthropocene emerged. Prior debates have highlighted a range of difficulties in pinpointing these causes. For example, it is nearly impossible to correlate the causes of planetary changes directly with their respective effects; even a complex systems approach alone is insufficient to account for them. Niche construction theory provides us with a new perspective on the causes and effects of the Anthropocene, allowing us to reconcile the Earth complex systems approach with human-induced changes in this system.

Although popular in ecological and biological sciences, in archaeology niche construction theory has been largely neglected. However, not only are humans' behavioral changes visible on a global scale, these changes have been recorded in archaeological data. From a geoarchaeological perspective, human niche construction is the ability of humans to adapt to their environment or to alter it to such an extent that anthropogenic cycles change, or even replace, natural cycles. Humans are considered the ultimate niche constructors (Odling-Smee et al. 2003), because their influence is currently far more intrusive and overwhelming than that of any other living creature on Earth.

We argue that it is possible to date the onset of the Anthropocene through an analysis of global changes in human niche construction using (geo)archaeological data, which sheds light on why the Anthropocene began. In particular, this essay addresses three issues that together offer a new perspective on the causes and effects of the Anthropocene: how the onset of the Anthropocene has been determined so far, especially in the geologic record; the importance of human activity in determining the causes of anthropogenic change; and finally, how these approaches combined offer an alternative explanation for the onset of the Anthropocene—one that corresponds to the concept

of "runaway sociocultural niche construction," which requires an ongoing cycle of adaptation to human-induced changes (Ellis 2015).

Defining the Anthropocene

Coined in 1999 at a conference by Nobel Laureate Paul Crutzen, the proposed geological epoch of the Anthropocene marks the termination of the Holocene (Crutzen and Stoermer 2000) and recognizes the significant global impact of human activities on the Earth's ecosystems. But how are we able to identify the transition from one epoch to the next? What evidence do we use and what form does it take? To decide the lower boundary of an age— i.e., when it began—geologists use the GSSP (Global Stratotype Section and Point). A GSSP defines the baseline of the deposits from the stratigraphic period to which the GSSP is related. It stands to reason that for this evidence to be widely present in the geologic record, events must occur at a global scale. Geological processes may be characterized by exceptional large-scale changes, such as meteoritic impact, supervolcanism, continental shift, mass extinction, or by cyclic climate oscillations in the system. However, there are exceptions such as the Holocene, whose lower boundary is defined (in an ice core) by a number of years rather than by geological evidence—in this case, 10,000 carbon years before present (BP). Following this logic, geological data alone are not sufficient to define the Anthropocene; we should also take into account human activity, which has affected the Earth substantially. While the geological timescale is based on observable changes in the Earth's crust, signs of human activity are recorded in different ways at different times and in different places.

The Industrial Revolution (1750–1800 CE) has been proposed as one possible onset of the Anthropocene, since increased concentrations of methane and carbon dioxide resulted in global atmospheric changes. Another suggestion is that the atomic explosions of 1945 were responsible for a record change in the amount of measurable radionuclides (Waters et al. 2016). Agriculture and global atmospheric changes from 8000–5000 BP led to the "early anthropogenic CH_4 hypothesis," where notable increases in methane (CH_4) were attributed to the spread of early agriculture, specifically rice cultivation in Asia around 8000 BP (Ruddiman et al. 2008). We can also trace changes in the Earth's surface from human activity: hunter-gatherers in the early Holocene impacted the terrain through harvesting and overhunting, which changed plant

and animal populations; since then, much of the terrestrial planet has been modified by sedentary civilizations. They have altered the soil through plowing, fertilizers, contamination, soil sealing—a loss of soil resources due to housing and infrastructure construction—and even embellished the land with artifacts.

Given the validity of all of these theories, it is clear why it has been so difficult to isolate the causes of anthropogenic changes and the advent of the Anthropocene.

Complex Systems and the Inadequacy of the Nature/Culture Dichotomy

The Anthropocene is based on the premise that humans—just one species—have gained the capacity to transform the Earth system; it is therefore important to recognize human exceptionalism as a relatively novel global force. Moreover, because humans are both researcher and research subject, the Anthropocene discussion must take into consideration the values and possible biases of the researcher, rather than simply be limited to the Earth sciences. The concept of the Anthropocene has implications far beyond the spectrum of geological sciences into social, political, legal, psychological, philosophical, and cultural disciplines, as well as the arts. Given the inherent complexity of human psychology and human societies, we need to approach human interactions with the environment from a holistic perspective.

So far, the dialectic between nature and culture has persisted in climate change and Anthropocene debates. Nature constitutes natural processes, neither touched nor influenced by humans, acting on the Earth system; whereas Culture refers to the material cultural remnants of past and current societies, as well as the natural processes that have been modified and/or encouraged by human actions. However, the reduction of the Earth system to an opposition between humans and their environment has brought the discussion to an impasse. Terms like "nature," "culture," or "natural environment" are often too broad in meaning—for instance, the concept of ecosystems better reflects the systemic relations of the ensemble of life (including humans) and its physical environment than "natural environment" (Ellis 2015). So, it is interesting that, even though global Earth modeling works on the premise that Earth is a complex system, people continue to use this linear nature/culture approach. The complex systems approach addresses the issue in a more holistic way, integrating humans fully as an element of the Earth system.

Climate change is an example of a complex system: the gradual rise in carbon dioxide concentrations may have a limited impact on climate until it reaches a certain threshold, which triggers a brutal change in the Earth system. In this case, causes and consequences do not have a direct correlation, which makes it rather difficult to establish the trigger using a linear approach. Complex systems move between stable states and are driven by major feedback loops. They are also resilient to disturbance and do not necessarily react linearly to changes. This can further be seen in a gradually eroding valley, where the system is forced past a bifurcation point: when the lateral erosion of rivers removes the ridge that divides two separate stream valleys, the drainage system, and therefore landscape stability, suddenly changes. This makes predicting responses much harder given their abrupt nature. The effects of changes can therefore be *asynchronous*, *inverse*, and/or *disproportional* to the causes. The complex systems approach complements the nature/culture approach by showing how effects can be indirect and disproportional, even if they are caused by human activities. The concept of human niche construction is a useful way to account for the human role in environmental change while also focusing on the fact that these changes do not take place in a vacuum; rather they are embedded in networks of reciprocal interactions and involve adaptations of both species and ecosystems.

Human Niche Construction as Key to Defining the Anthropocene

At different rates and scales, humans have transformed their environment to make it safer and more comfortable. Just as beavers build dams to control water management and change river flow patterns in the process, humans build dams to generate hydroelectric power, to create transport routes, and to create safety for populations and impose groundwater and salt/sweet water flow regimes. We are also able to respond to new challenges by modifying our behavior, such as when we ban the manufacture of chlorofluorocarbons (CFCs) because they are responsible for the "hole" in the ozone layer, endangering the protection it offers against high doses of UV radiation. As a result, our species has relieved itself of a broad range of selective pressures, such as temperature, food production, and disease. Species affect evolutionary trajectories by acting on their selective environment and we can consider niche construction to be an evolutionary process (Laland and Brown 2006). Our species has the remarkable ability to adapt its niche construction behavior to achieve its goals in a broad spectrum of ecosystems (Odling-Smee et al. 2003).

Figure 1:
Schwarzbach pond and peat bog (Kuchelscheid, Belgium). Photo by Jacopo Werther (CC BY-SA 2.0).

According to Smith and Zeder (2013) niche construction behavior can be traced as far back as the early hominids, but substantial change in human behavior occurred at the beginning of the Holocene (ca. 11,000–9000 BP). At this point in human history, at different locations across the globe, a major shift occurred in humans' adaptation of the surrounding ecosystem: the domestication of plants and animals. Just as we altered our environment to accommodate them, these domesticates substantially modified their ecosystem in turn—e.g., by introducing new arable species and exploiting an as yet untouched animal resource—and so we have been able to record this shift in subsistence and niche construction behavior within the framework of the social sciences. Niche construction can be divided into two categories: inceptive and counteractive (Kluiving et al. 2015). Inceptive niche construction refers to the initial modification of an environment, as might happen when a species migrates to a region for the first time or adopts new behaviors. Six thousand years ago in the western Netherlands people reacted to the threat of the rising sea level by raising the ground surface level with reed bushes, or moving to higher and drier places. Counteractive niche construction occurs as an adaptive response to an environment that has already been altered. The effects of deforestation on river sedimentation processes and early water management

measures can be considered counteractive changes. It is this second model that is particularly relevant as a way of thinking about the Anthropocene.

We propose that the Anthropocene emerges as a "tipping point from inceptive to counteractive changes," which corresponds to the concept of "runaway sociocultural niche construction," as outlined by Ellis (2015). This particular transition emerges when continued human impact on ecosystems results in sustained changes to our environment, locking us into an ongoing cycle of adaptation. Although niche construction processes can also be seen in hunter-gatherer societies, for example in niche broadening—diversifying the type of animal hunted based on species extinction rates—it is the capacity to sustain this process, not just one phase or the other, that enables societies to gain the capacity to act on the Earth system at global scales and thus "cause" the Anthropocene.

Studies in this area similarly tend to focus on the causes of system changes rather than the effects. In the western Netherlands, for example, the sustained industrial extraction of peat has led to an unprecedented drop in the ground surface of approximately 10 meters across the entire coastal zone—an irreversible human-induced counteractive change that has caused significant flooding of the inhabited landscape. The Celtic cultivation of agricultural fields in the southeastern Netherlands led to soil degeneration in loam-deprived soils, which resulted in (sustained) mass migrations around 3000 BP. A comparison of these and several geoarchaeological case studies from northwestern Europe to the eastern Mediterranean reveals that the tipping point from inceptive to counteractive changes appears to parallel the onset of domestication (in Kluiving 2015; cf. Widgren 2012), although more research is needed to test this hypothesis.

Therefore, though the Holocene and Anthropocene are coeval, their causes differ: the focus "shifts … away from gaseous emissions of smoke stacks and livestock, spikes in pollen diagrams, or new soil horizons of epochal proportions to a closer consideration of regional-scale documentation of the long and complex history of human interaction with the environment that stretches back to the origin of our species up to the present day" (Smith and Zeder 2013).

In the years since the Industrial Revolution, humanity has not only exploited the environment and domesticated our landscapes—we have assumed *responsibility* for it. Some call this new environmental awareness the "green revolution," promising a sweeping change in human society and culture comparable to the Neolithic Revolution or the Industrial Revolution. This revolution, too, will likely have some kind of global impact on the Earth system in the future—at least, that is its goal—and might even be recorded as another geological subdivision (perhaps a sub-phase within the Anthropocene). Establishing *why* the Anthropocene began rather than *when* it began reinforces the search for proof that humankind is indeed responsible for global anthropogenic change. We believe that through transdisciplinary research involving the nature/culture dialectic and geoarchaeology, this shift in responsibility will eventually result in a corresponding duty of care towards nature and sustainable solutions for our planet.

Further Reading:

Crutzen, Paul, and Eugene Stoermer. 2000. "The Anthropocene." *IGBP Newsletter* 41: 17–18.

Ellis, Erle C. 2015. "Ecology in an Anthropogenic Biosphere." *Ecological Monographs* 85 (3): 287–331. (ESA Centennial Paper) doi: 10.1890/14-2274.1.

Kluiving, Sjoerd J. 2015. "How Geoarchaeology and Landscape Archaeology Contribute to Niche Construction Theory (NCT)." *Water History* 7 (4): 557–71. doi: 10.1007/s12685-015-0144-8.

Kluiving, Sjoerd J., Marijke Bekkema, and Nico Roymans. 2015. "Mass Migration through Soil Exhaustion: Transformation of Habitation Patterns in the Southern Netherlands (1000 BC–500 AD)." *Catena* 132: 139–50. doi: 10.1016/j.catena.2014.12.015.

Laland, Kevin N., and Gillian R. Brown. 2006. "Niche Construction, Human Behavior, and the Adaptive-Lag Hypothesis." *Evolutionary Anthropology* 15 (3): 95–104. doi: 10.1002/evan.20093.

Lewis, Simon L., and Mark A. Maslin. 2015. "Defining the Anthropocene." *Nature* 519 (7542): 171–80. doi:10.1038/nature14258.

Odling-Smee, F. John, Kevin N. Laland, and Marcus W. Feldman. 2003. *Niche Construction: The Neglected Process in Evolution*. Princeton, NJ: Princeton University Press.

Ruddiman, William F., Zhengtang Guo, Xin Zhou, Hanbin Wu, and Yanyan Yu. 2008. "Early Rice Farming and Anomalous Methane Trends." *Quaternary Science Reviews* 27 (13–14): 1291–95.

Smith, Bruce D., and Melinda A. Zeder. 2013. "The Onset of the Anthropocene." *Anthropocene* 4: 8–13.

Waters, Colin N., Jan Zalasiewicz, Colin Summerhayes, Anthony D. Barnosky, Clément Poirier, Agnieszka Gałuszka, Alejandro Cearreta, et al. 2016. "The Anthropocene is Functionally and Stratigraphically Distinct from the Holocene." *Science* 351 (6269). doi: 10.1126/science.aad2622.

Widgren, Mats. 2012. "Landscape Research in a World of Domesticated Landscapes: The Role of Values, Theory, and Concepts." *Quaternary International* 251: 117–24.