Anthropocene xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Anthropocene

journal homepage: www.elsevier.com/locate/ancene

The onset of the Anthropocene

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ARTICLE INFO

Keywords:
Niche construction
Domestication
Agriculture
Climate change

ABSTRACT

A number of different starting dates for the Anthropocene epoch have been proposed, reflecting different disciplinary perspectives and criteria regarding when human societies first began to play a significant role in shaping the earth's ecosystems. In this article these various proposed dates for the onset of the Anthropocene are briefly discussed, along with the data sets and standards on which they are based. An alternative approach to identifying the onset of the Anthropocene is then outlined. Rather than focusing on different markers of human environmental impact in identifying when the Anthropocene begins, this alternative approach employs Niche Construction Theory (NCT) to consider the temporal, environmental and cultural contexts for the initial development of the human behavior sets that enabled human societies to modify species and ecosystems more to their liking. The initial domestication of plants and animals, and the development of agricultural economies and landscapes are identified as marking the beginning of the Anthropocene epoch. Since this transition to food production occurred immediately following the Pleistocene–Holocene boundary, the Anthropocene can be considered as being coeval with the Holocene, resolving the contentious ''golden spike'' debate over whether existing standards can be satisfied for recognition of a new geological epoch.

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1. Introduction

In 2000 Paul Crutzen and Eugene Stoermer proposed that human modification of the global environment had become significant enough to warrant termination of the current Holocene geological epoch and the formal recognition of a new 'Anthropocene' epoch (Crutzen and Stoermer, 2000; Crutzen, 2002). Although their term 'Anthropocene' was new, they cite a number of similar proposals for terminological recognition of human dominance of the earth's ecosystems that had been made over the last 140 years. The 'Anthropocene' epoch initiative was primarily intended to draw attention to the serious ongoing challenge that faces mankind:

> A daunting task lies ahead for scientists and engineers to guide society toward environmentally sustainable management during the era of the Anthropocene. (Crutzen, 2002, p. 23)

Although primarily intended to underscore the seriousness of the accelerating environmental challenges facing humanity, this call for a revision of geological nomenclature has also attracted the attention of researchers interested in characterizing the Anthropocene, particularly in regard to accurately establishing the temporal boundary between the Holocene and the proposed new Anthropocene epoch. When exactly did humans attain dominance of the earth's environments? Underlying the efforts by scientists in different disciplines to identify this Holocene–Anthropocene transition are several basic questions: which stratigraphic, atmospheric, and biotic variables, for example, should take precedence in establishing the onset of the Anthropocene, how significant a change in value of these variables should be expected, and should the transition be tracked at a global or regional scale of analysis?

In this article we begin by briefly summarizing and comparing the various approaches that have been taken in defining the Holocene–Anthropocene transition over the past decade by scholars across a range of disciplines, looking in particular at the variety and utility of different criteria of change that are used and the degree to which these proposed beginning points for the Anthropocene have been shaped by the perceived necessity of conforming to established protocols and criteria used to define previous geologic boundaries. We conclude this discussion with consideration of a recently proposed consensus solution that is strongly shaped by extant geological standards and that situates the start of the Anthropocene at A.D. 1800 (Steffen et al., 2011).

We then contrast this position with our own alternative perspective that places the onset of the Anthropocene almost ten thousand years earlier, at the Pleistocene–Holocene boundary. In our view the beginning of the Anthropocene can be usefully defined in terms of *when evidence of significant human capacity for*

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2213-3054/$ – see front matter. Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.ancene.2013.05.001

ecosystem engineering or niche construction behaviors first appear in the archeological record on a global scale. While there is certainly evidence for a range of different forms of human niche construction prior to the Pleistocene–Holocene boundary (Groube, 1989; Smith, 2011, p. 836), these earlier human niche construction behavior sets provided human societies with only a limited ability to reshape ecosystems. In contrast, the domestication of a wide variety of species of plants and animals world-wide in the early Holocene provided human societies for the first time with the ability to significantly modify ecosystems. These domesticates constituted a major new type of human niche construction, and formed the basis for the subsequent development and still ongoing global expansion of agricultural landscapes. Rather than there being a Holocene–Anthropocene transition, we propose that it is more accurate, and more useful, to consider the two epochs to be one and the same or coeval – that the Anthropocene epoch extends back across the entire Holocene, and that the various boundary points that have been proposed over the past decade as marking the Holocene–Anthropocene boundary are more fruitfully recognized as defining successive phases within the Holocene/Anthropocene epoch.

2. Alternative temporal boundaries for the Holocene–Anthropocene transition

Over the past decade efforts to identify the starting point of the newly proposed Anthropocene epoch have been based largely on addressing four interrelated questions: (1) level of human control – what degree of human modification and control of earth's environments is necessary to initiate the Anthropocene; (2) geographical scale – over how much of the earth's land surface does such human intervention in the earth's environments have to be documented to initiate the Anthropocene; (3) relevant data sets – what kinds of information are appropriate and acceptable to employ in marking the beginning of the Anthropocene; and (4) to what extent should the established protocols and criteria employed by the International Commission on Stratigraphy (ICS) to define previous geologic boundaries be adhered to in establishing a lower boundary to the Anthropocene? Based on the manner in which these four questions were answered, alternative proposed starting dates for the Holocene–Anthropocene are scattered across more than ten millennia, from 13,800 B.P. to A.D. 1750 (Fig. 1) (all B.P. dates in this article are in calibrated calendar years). Perhaps not surprisingly, researchers have often found the most significant indicators of the Holocene–Anthropocene transition, and sometimes the only indicators of interest, within the boundaries of their own discipline.

2.1. *A.D. 1750–1800: the industrial revolution and global atmospheric change*

In first proposing the use of the term "Anthropocene" for the current geological epoch Crutzen and Stoermer (2000) identify the latter part of the 18th century as marking the Holocene–Anthropocene boundary because it is over the past two centuries that the global effects of human activities have become clearly noticeable. Although they discuss a wide range of different defining characteristics of the Anthropocene epoch (e.g., human population growth, urbanization, mechanized predation of fisheries, modification of landscapes), Crutzen and Stoermer (2000)

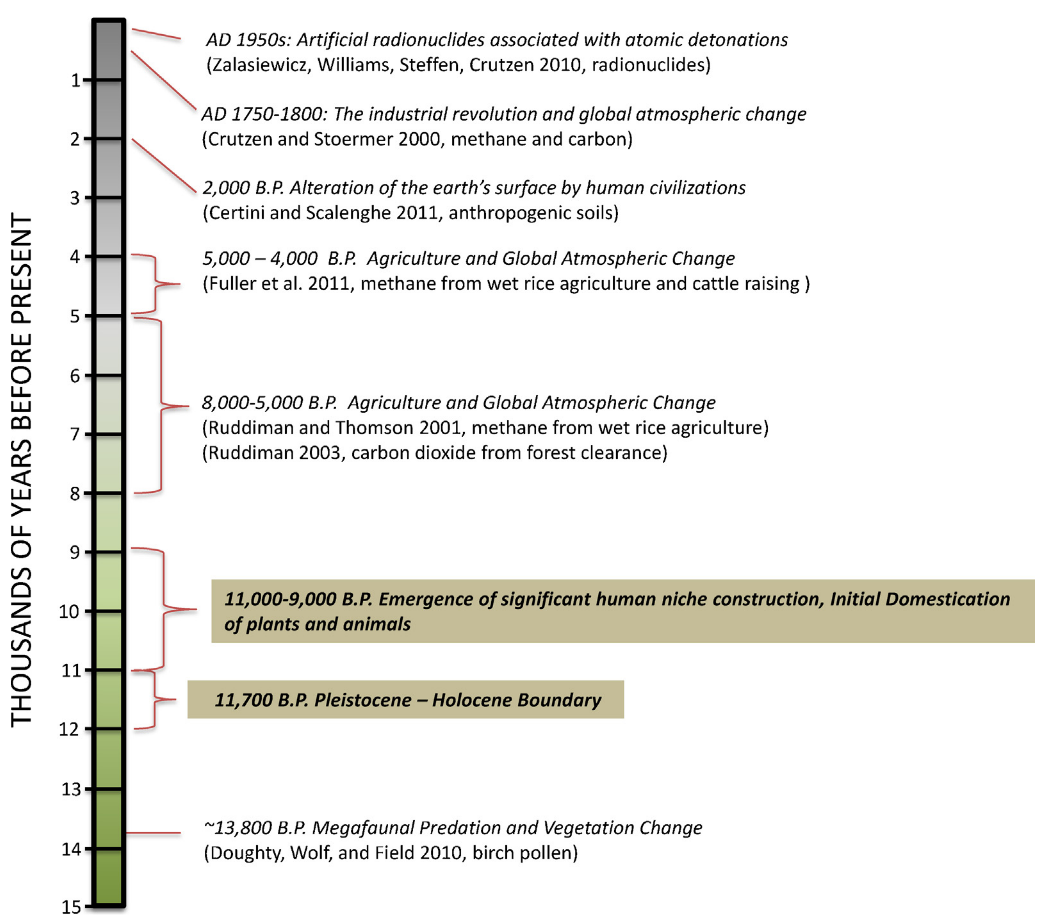

Fig. 1. Alternative temporal boundaries for the Holocene–Anthropocene boundary (time scale in calibrated calendar years before present).

Please cite this article in press as: Smith, B.D., Zeder, M.A., The onset of the Anthropocene. Anthropocene (2013), http://dx.doi.org/10.1016/j.ancene.2013.05.001

identify global scale atmospheric changes (increases in carbon dioxide and methane) resulting from the industrial revolution as the key indicator of the onset of the Anthropocene: "This is the period when data retrieved from glacial ice cores show the beginning of a growth in the atmospheric concentrations of several "greenhouse gases", in particular CO_2 and CH_4...Such a starting date also coincides with James Watt's invention of the steam engine" (Crutzen and Stoermer, 2000, p. 17).

At the same time that they propose placing the Holocene–Anthropocene boundary in the second half of the 18th century, and identify a single global scale marker for the transition, Crutzen and Stoermer (2000) also acknowledge that human modification of the earth's ecosystems has been gradually increasing throughout the post-glacial period of the past 10,000–12,000 years, and that other Holocene–Anthropocene transition points could be proposed: "During the Holocene mankind's activities gradually grew into a significant geological, morphological force"; "To assign a more specific date to the onset of the "Anthropocene" seems somewhat arbitrary"; "we are aware that alternative proposals can be made (some may even want to include the entire holocene)" (Crutzen and Stoermer, 2000, p. 17).

2.2. 2000 B.P. alteration of the earth's surface by human civilizations

In a 2011 article, two soil scientists, Giacomo Certini and Riccardo Scalenghe, question whether the Anthropocene starts in the late 18th century, and reject Crutzen and Stoermer's use of an increase in greenhouse gasses associated with the industrial revolution as an onset marker. They argue that a "change in atmospheric composition is unsuitable as a criterion to define the start of the Anthropocene", both because greenhouse gas levels do not reflect the "substantial total impact of humans on the total environment ", and because "ice layers, with their sealed contaminated air bubbles lack permanence" since "they are prone to be canceled by ongoing climatic warming" (Certini and Scalenghe, 2011, pp. 1270, 1273).

Instead of using atmospheric composition as a marker, they propose employing anthropogenic soils as a "golden spike" or GSSP (Global Stratigraphic Section and Point) indication of the beginning of the Anthropocene. Anthropogenic soils or Anthrosols – "soils markedly affected by human activities, such as repeated plowing, the addition of fertilizers, contamination, sealing, or enrichment with artifacts" have the advantage, they argue, of following stratigraphic criteria for such geological boundary markers in that they provide clear and permanent "memories of past, widespread, anthropic interventions on the environment." (Certini and Scalenghe, 2011, p. 1271). They conclude that "the pedosphere is undoubtedly the best recorder of such human-induced modifications of the total environment", and identify "a late Holocene start to the Anthropocene at approximately 2000 yrs B.P. when the natural state of much of the terrestrial surface of the planet was altered appreciably by organized civilizations" (2011, p. 1273).

The value of anthropogenic soils in identifying the base of the Anthropocene in stratigraphic sequences has recently been questioned however, due to their poor preservation potential, their absence in many environments, and the worldwide diachroneity of human impact on the landscape:

> More significantly, much of the work undertaken on the Anthropocene lies beyond stratigraphy, and a stratigraphic definition of this epoch may be unnecessary, constraining and arbitrary. It is not clear for practical purposes whether there is any real need for a golden spike at the base of the Anthropocene. The global stratigraphic approach may prove of limited utility in studies of human environmental impact. (Gale and Hoare, 2012)

The limited utility of stratigraphic criteria in establishing a Holocene–Anthropocene boundary has been underscored by a number of other researchers (e.g., Zalasiewicz et al., 2010), as has the existence of other, admittedly too recent, potential pedospheric markers, including the post-1945 inclusion in the world's strata of measurable amounts of artificial radionuclides associated with atomic detonations (Zalasiewicz et al., 2008, p. 7, 2010, p. 2230).

2.3. 8000–5000 B.P. agriculture and global atmospheric change

At the same time that Crutzen and Stoermer (2000) were placing the beginning of the Anthropocene at A.D. 1750–1800 based on a dramatic observed increase in carbon dioxide and methane in the ice core record, Ruddiman and Thomson (2001) were focusing on a much earlier and more gradually developing increase in methane in the Greenland ice core record and arguing that around 5000 cal B.P., well before the industrial era, human societies had begun to have a detectable influence on the earth's atmosphere.

After exploring and rejecting two previously suggested natural causes for the observed methane shift at about 5000 B.P. (peatland and natural tropical wetland source hypotheses), and concluding that the only plausible source for enhanced methane input beginning five millennia ago was human activity, Ruddiman and Thomson propose, and present supporting evidence for, an "early anthropogenic CH_4 hypothesis" (2001, p. 1772). Five different human activities are identified as potential early anthropogenic methane inputs: (1) generating human waste; (2) tending methane-emitting (i.e. belching and flatulence) livestock; (3) animal waste; (4) burning seasonal grass biomass; and (5) irrigating rice paddies (Ruddiman and Thomson, 2001; Ruddiman et al., 2008, p. 1292). Of these, inefficient wet rice agriculture is identified as the most plausible major source of increased anthropogenic methane input to the atmosphere. Anaerobic fermentation of organic matter in flooded rice fields produces methane, which is released into the atmosphere through the roots and stems of rice plants (see Neue, 1993). While Ruddiman and Thomson do not employ the specific term "Anthropocene" in their discussion, they push back the onset of human impact on the earth's atmosphere to 5000 B.P., and label the time span from 5000 up to the industrial revolution as the "early anthropogenic era" Ruddiman and Thomson (2001, Figure 3).

Following its initial presentation in 2001, William Ruddiman has expanded and refined the "early anthropogenic era" hypothesis in a series of articles (Ruddiman, 2003, 2004, 2005a,b, 2006, 2007; Ruddiman et al., 2008; Ruddiman and Ellis, 2009). In 2008, for example, Ruddiman and Chinese collaborators (Ruddiman et al., 2008) offer additional support for the early anthropogenic CH_4 hypothesis by looking at another test implication or marker of the role of wet rice agriculture as a methane input. The number and geographical extent of archeological sites in China yielding evidence of rice farming is compiled in thousand year intervals from 10,000–4000 B.P., and a dramatic increase is documented in the number and spatial distribution of rice farming settlements after 5000 B.P. (Ruddiman et al., 2008, p. 1293). This increase in rice-based farming communities after 5000 B.P. across the region of China where irrigated rice is grown today suggests a dramatic early spread of wet rice agriculture.

In a more recent and more comprehensive study of the temporal and spatial expansion of wet rice cultivation in China, Fuller et al. (2011, p. 754) propose a similar timeline for anthropogenic methane increase, concluding that: "the growth in wet rice lands should produce a logarithmic growth in methane emissions significantly increasing from 2500 to 2000 BC, but especially after that date". Fuller et al. also make an initial effort to model the global expansion of cattle pastoralism in the same general time span (3000–1000 BC), and suggest that: "during this period the methane from livestock may have been at least as important an anthropogenic methane source as rice" (2011, p. 756).

In addition to considering archeological evidence for the role of wet rice agriculture in increasing methane levels during the early anthropogenic era, Ruddiman also returns to the Greenland ice core record to look at atmospheric levels of the second major greenhouse gas – carbon dioxide (CO_2). Two proposed natural causes for an observed increase in CO_2 around 8000 years ago (natural loss of terrestrial biomass and changes in ocean carbonate chemistry) are considered and rejected. Instead, the rise in CO_2 is attributed to the widespread initial pre-industrial forest clearance in Eurasia associated with the expansion of agricultural landscapes (Ruddiman, 2003). This increase in CO_2 is characterized as being "imperceptibly gradual, and partially masked by a larger cooling trend" (2003, p. 285).

The supporting evidence offered for deforestation associated with agriculture being the cause of the observed CO_2 rise at ca. 8000 B.P. is also admittedly limited: "these estimates of land clearance and carbon emissions are obviously just rough first approximations" (2003, p. 277), consisting of general observations regarding the initial expansion of agricultural societies out of the Near East into Europe and their subsequent intensification, as well as similar but less well documented trends in China and India.

2.4. ~13,800 B.P. megafaunal predation and vegetation change

Like Certini and Scalenghe, ecologists Christopher Doughty, Adam Wolf, and Christopher B. Field (2010) use a pedospheric indicator to mark the beginning of the Anthropocene, but focus on a much smaller, regional scale of proposed human impact. Their proposed marker for the onset of the Anthropocene is a large increase in Birch (*Betula*) pollen from Alaska and the Yukon during a narrow 1000 year period at ~13,800 B.P. They suggest that this increase in *Betula* modified the land surface albedo (i.e. reduced reflectivity), resulting in a projected regional warming of up to 1 °C.

Given the general temporal correlation between this documented increase in *Betula* and the extinction of mammoths, they hypothesize that reduced herbivory associated with the disappearance of megafauna played a causal role in the expansion of birch forests and the resultant rise in regional temperature levels. The extinction of mammoths is then linked to human predation, and they propose that humans contributed to global warming:

> We hypothesize that the extinction of mammoths increased *Betula* cover, which would have warmed Siberia and Beringia by on average 0.2 degrees C, but regionally by up to 1 degree C. If humans were partially responsible for the extinction of mammoths, then human influences on global climate predate the origin of agriculture. (Doughty et al., 2010)

They go on to conclude that this anthropogenic regional warming trend represents the onset of the Anthropocene: "Together, these results suggest that the human influence on climate began even earlier than previously believed (Ruddiman, 2003), and that the onset of the Anthropocene should be extended back many thousand years." (Doughty et al., 2010).

2.5. An emerging industrial revolution consensus

Following the development of a range of different potential start dates for the Anthropocene over the past decade, a consensus solution to establishing its lower boundary now seems to be emerging, based on a recent theme issue of the *Philosophical Transactions of the Royal Society A*: (Ellis et al., 2011; Steffen et al., 2011; Zalasiewicz et al., 2011a,b). Rather than constituting a formal chronostratatgraphic definition of the Anthropocene epoch, this consensus adopts, as a practical measure, a beginning date in the past 50–250 years:

> In this paper, we put forward the case for formally recognizing the Anthropocene as a new epoch in Earth history, arguing that the advent of the Industrial Revolution around 1800 provides a logical start date for the new epoch. (Steffen et al., 2011, p. 842)
> The Anthropocene, on current evidence, seems to show global change consistent with the suggestion that an epoch-scale boundary has been crossed within the last two centuries". (Zalasiewicz et al., 2011a, p. 840)
> ...for current practical purposes, a GSSP may not be immediately necessary. At the level of resolution sought, and at this temporal distance, simply selecting a numerical age, such as the beginning of 1800 in the Christian Gregorian calendar, may be an equally effective practical measure. (Zalasiewicz et al., 2011b, p. 1050)
> ...by the latter half of the twentieth century, the terrestrial biosphere made the transition from being shaped primarily by natural biophysical processes to an anthropogenic biosphere in the Anthropocene, shaped primarily by human systems. (Ellis, 2011, p. 1029)

Steffen et al. (2011) follow the lead of Crutzen and Stoermer (2000) in identifying the rapid and substantial global increase in greenhouse gasses associated with the Industrial Revolution as marking the onset of the Anthropocene, while also documenting a wide range of other rapid increases in human activity since 1750, from the growth of McDonald's restaurants to expanded fertilizer use (Steffen et al., 2011, p. 851). In identifying massive and rapid evidence for human impact on the earth's atmosphere as necessary for defining the Holocene–Anthropocene transition, and requiring such impact to be global in scale, Steffen et al. (2011) are guided by the formal criteria employed by the International Commission on Stratigraphy (ICS) in designating geological time units. Such formal geologic criteria also play a central role the analysis of Zalasiewicz et al. (2011b) in their comprehensive consideration of potential and observed stratigraphic markers of the Anthropocene: "Thus, if the Anthropocene is to take it's place alongside other temporal divisions of the Phanerozoic, it should be expressed in the rock record with unequivocal and characteristic stratigraphic signals." (Zalasiewicz et al., 2011b, p. 1038). Ellis et al. (2011) also looks for rapid and massive change on a global scale of assessment in his consideration of human transformation of the terrestrial biosphere over the past 8000 years, and employs a standard of "intense novel anthropogenic changes ...across at least 20 per cent of Earth's ice-free land surface" as his criteria for "delimiting the threshold between the wild biosphere of the Holocene and the anthropogenic biosphere of the Anthropocene" (2011, p. 1027).

3. An alternative perspective on the onset of the Anthropocene

A quite different, and we think worthwhile, approach to defining the onset of an Anthropocene epoch avoids focusing exclusively and narrowly on when human alteration of the earth systems reached "levels of equal consequence to that of past biospheric changes that have justified major divisions of geological time" (Ellis, 2011, p. 1027). We argue that the focus should be on cause rather than effect, on human behavior: "the driving force for the component global change" (Zalasiewicz et al., 2011a, p. 838), rather than on continuing to debate what type and what degree of environmental degradation qualifies as a "golden spike" for establishing the proposed new geological epoch.

In addition, we suggest that somewhere in the decade of debate regarding how to define the onset of the Anthropocene in a manner that will conform to the guidelines of the International Commission on Stratigraphy of the International Union of Geological

Sciences in designating geological time units, the basic underlying reason for creating geological time units has been overlooked. The value of designating a new Anthropocene epoch rests on its utility in defining a general area of scientific inquiry – in conceptually framing a broad research question. Like the Holocene epoch, the value of an Anthropocene epoch can be measured by its practical value:

> The Holocene is really just the last of a series of interglacial climate phases that have punctuated the severe icehouse climate of the past 2Myr. *We distinguish it as an epoch for practical purposes*, in that many of the surface bodies of sediment on which we live – the soils, river deposits, deltas, coastal plains and so on – were formed during this time. (Zalasiewicz et al., 2011a, p. 837) [emphasis added]

In considering the practical or utility value of designating a new Anthropocene epoch, the emphasis, the primary focus, we think, should be placed on gaining a greater understanding of the long-term and richly complex role played by human societies in altering the earth's biosphere (e.g., Kirch, 2005). This proposed deep time consideration of significant ecosystem engineering efforts by human societies provides a clear alternative to the shallow temporal focus on the major effects of human activities over the last two centuries that defines the Industrial Revolution consensus:

> While human effects may be detected in deposits thousands of years old...major unequivocal global change is of more recent date... It is the scale and rate of change that are relevant here, rather than the agent of change (in this case humans). (Zalasiewicz et al., 2011b, p. 1049)

In turning attention to the agent of change – patterns of human activity intended to modify the earth's ecosystems, the beginning of the Anthropocene epoch can be established by determining when unequivocal evidence of significant human ecosystem engineering or niche construction behaviors first appear in the archeological record on a global scale. As we discuss below, there is a clear and unequivocal hard rock stratigraphic signal on a global scale that marks the initial domestication of plants and animals and defines the onset of the Anthropocene.

Ecosystem engineering or niche construction is not, of course, a uniquely human attribute. Many animal species have been observed to modify their surroundings in a variety of ways, with demonstrable impact on their own evolutionary trajectories and those of other affected species (e.g., the beaver (*Castor canadensis*) (Odling-Smee et al., 2003). One of the basic attributes that sets our species apart from other niche-constructing animals, however, is our remarkable ability to create new niche-constructing behaviors and to broadly transmit these behaviors across generations through social learning. It is this greatly enhanced capacity to modify our surroundings to meet certain perceived goals that make humans "the ultimate niche constructors" (Odling-Smee et al., 2003, p. 28; Smith, 2007a,b, 2012). The emergence of the capacity for significant human ecosystem engineering marks a major evolutionary transition in Earth's history, as human societies begin to actively and deliberately shape their environments in ways and to an extent never before seen. The initial appearance of unequivocal evidence for significant human modification of the earth's ecosystems on a global scale thus provides a natural beginning point for the Anthropocene.

As a basic adaptive attribute of our species, environmental manipulation or niche construction likely stretches back to the origin of modern humans, if not earlier. Substantial, sustained, and intensive efforts at ecosystem engineering, however, do not become evident in the archeological record until the end of the last Ice Age, particularly in those resource-rich areas that arose across the world with the amelioration and stabilization of climate in the Early Holocene (Smith, 2006, 2011, 2012; Zeder, 2011). These environments, made up of a mosaic of terrestrial and aquatic eco-zones supporting diverse arrays of abundant and predictable resources, encouraged more sedentary subsistence strategies based on the exploitation of a broad-spectrum of resources within a defined catchment area (Smith, 2006, 2007a,b, 2011, 2012; Zeder, 2012a). The diversity and richness of biotic communities in such environments, moreover, offered humans greater opportunities for experimentation with different approaches to modifying environments in ways intended to increase human carrying capacity, thus protecting the long term investment made by communities in local ecosystems (Zeder, 2012a). Although general evidence for this global intensification of human niche construction efforts in the early Holocene is limited in many respects, and for a variety of reasons (Smith, 2011), one result of increased human manipulation of biotic communities does stand out – the appearance of domesticated plants and animals.

These sustained, multi-generation human efforts at manipulating and increasing the abundance of economically important species in resource-rich environments during the Early Holocene (ca. 11,000–9000 B.P.) provided the general co-evolutionary context within which human societies world-wide brought a select set of pre-adapted species of plants and animals under domestication (Smith, 2006, 2007a,b, 2011, 2012; Zeder, 2012b,c) (Figure 2). These domesticates in turn have provided the lever with which we have transformed much of the earth into agricultural landscapes that feed an ever increasing global population, and it is this domestication process, we argue, that provides the archeological signature for major human manipulation of terrestrial ecosystems, and the onset of the Anthropocene.

Fortunately, clear and compelling documentation of both the nature and timing of initial domestication of a growing number of species world-wide, a hard rock stratigraphic sequence, has been steadily building over the past half century. Since the 1960s biologists and archeologists working from complementary perspectives have substantially improved our understanding of many different aspects of the initial domestication of plants and animals (e.g., Doebley et al., 2006; Zeder et al., 2006; Bar-Yosef and Price, 2011; Gepts et al., 2012). Although the quality and quantity of information that is currently available from the different independent centers of domestication varies greatly, as does the variety and relative present-day importance of the species brought under domestication, the important aspects of this major transition in earth's history in terms of the present discussion are: (1) archeobiological remains of early domesticates recovered from archeological sites represents a clear and compelling pedospheric record of the onset of the Anthropocene; (2) this constantly improving record of initial domestication occurs on a global scale – domestication occurred independently in different regions throughout the world – from the eastern United States south through Mexico to the southern Andes in the Americas, and from the Near East south into Africa and through the Indian Subcontinent into southeast Asia and east Asia in the Old World; (3) evidence in all but a few of these centers for the earliest domesticates fall into a narrow time span immediately following the Pleistocene–Holocene boundary (ca. 11,000–9000 B.P) (Bar-Yosef and Price, 2011); and (4) in each of these areas initial domestication led to ever expanding regionally tailored agricultural economies and a complex unfolding history of ever-increasing management and modification of the biosphere over the past 10,000 years. Researchers working at a regional scale of analysis in each of these areas continue to address a constantly expanding and increasing challenging set of important and rewarding developmental questions (Zeder and Smith, 2009).

In practical terms, it seems more useful to begin the Anthropocene when there is clear evidence on a global scale for human societies first developing the tools, in this case domesticates, that will be employed in reshaping the earth's terrestrial ecosystems over a span of the next 10,000 years, rather than limiting it to the last two centuries on the basis of extant geological standards.

Defining the onset of the Anthropocene in terms of the initial domestication of plants and animals world-wide 11,000–9000 years ago also resolves the serious challenge of satisfying geological standards for establishing a new epoch (Autin and Holbrook, 2012) in a much more compelling manner than the alternative starting dates that have been proposed, including the Industrial Revolution consensus. Placing the onset of the Anthropocene at the Pleistocene–Holocene boundary in effect makes it coeval with the Holocene, and removes the formal requirement of establishing a new geological epoch. The Holocene and Anthropocene epochs could on practical terms be merged into the Holocene/Anthropocene epoch, easily and efficiently encompassing 10,000 years of human modification of the earth's biosphere. Recognizing the coeval nature of the Holocene and Anthropocene epochs could also open up a number of interesting possibilities. The International Commission on Stratigraphy of the International Union of Geological Sciences, for example, might consider a linked nomenclature change: "Holocene/Anthropocene", with the term "Holocene" likely to continue to be employed in scientific contexts and "Anthropocene" gaining usage in popular discourse. Such a solution would seem to solve the current dilemma while also serving to focus additional attention and research interest on the past ten millennia of human engineering of the earth's ecosystems.

Situating the onset of the Anthropocene at 11,000–9000 years ago and making it coeval with the Holocene broadens the scope of inquiry regarding human modification of the earth's ecosystems to encompass the entirety of the long and complex history of how humans came to occupy central stage in shaping the future of our planet. It also shifts the focus 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.

Acknowledgements

We would like to thank Jon Erlandson and Todd Braje for their invitation to contribute to this special issue of *Anthropocene*, and for the thoughtful and substantial recommendations for improvement of our article that they and other reviewers provided.

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Please cite this article in press as: Smith, B.D., Zeder, M.A., The onset of the Anthropocene. Anthropocene (2013), http://dx.doi.org/10.1016/j.ancene.2013.05.001