The Anthropocene is functionally and stratigraphically distinct from the Holocene

Alejandro Cearreta
(UPV/EHU, Anthropocene Working Group)
(Steffen, W. et al., 2016. Earth's Future)
Global carbon dioxide budget
(gigatonnes of carbon per year)
2004-2013

Fossil fuel & cement
8.9 ± 0.4

Atmospheric growth
4.3 ± 0.1

Land-use change
0.9 ± 0.5

Land sink
2.9 ± 0.8

Ocean sink
2.6 ± 0.5

Geological reservoirs

Produced by the International Geosphere-Biosphere Programme for the Global Carbon Project.
EARTH'S GREAT SERVICE TO HUMANKIND

Half of the human emissions of CO₂ are absorbed by the planet's land and ocean ecosystems.

CO₂ absorbed by oceans

CO₂ absorbed by land

CO₂ left in the atmosphere

(Gt carbon/year)

1850 1900 1950 2000

The name Holocene ("Recent Whole") for the post-glacial geological epoch of the past ten to twelve thousand years seems to have been proposed for the first time by Sir Charles Lyell in 1830, and adopted by the International Geological Congress in Bologna in 1885 (5). During the Holocene mankind’s activities gradually grew into a significant geological, morphological, and, as recognised early on by a number of scientists, thus G.P. Marsh already in 1864 published a book with the title “Man and Nature”, more recently reprinted as “The Earth as Modified by Human Action” (20). Stoppani in 1873 rated mankind’s activities as a “new telic force which in power and universality may be compared to the greater forces of earth” (21). From the very beginning, mankind has inhabited or visited almost all places on Earth; he has even set foot on the moon. The great Russian geologist V.I. Vernadsky (4) in 1928 recognized the increasing power of mankind as part of the biosphere with the following excerpt “… the direction in which the processes of evolution must proceed, namely towards increasing consciousness and thought, and forms having greater and greater influence on their surroundings.” He, the French Jesuit P. Teilhard de Chardin and E. Le Roy in 1924 coined the term “noosphere”, the world of thought, to mark the growing role played by mankind’s brainpower and technological talents in shaping its own future and environment.

The expansion of mankind, both in numbers and per capita exploitation of Earth’s resources has been astounding (5). To give a few examples: During the past 3 centuries, human population increased tenfold to 6000 million, accompanied by a growth in cattle population to 1400 million (6) (about one cow per average-size family). Urbanization has much increased tenfold in the past century. In a few generations mankind is exhausting the fossil fuels that were generated over several hundred million years. The release of SO₂, globally about 160 Tg/year to the atmosphere by coal and oil burning, is at least two times larger than the sum of all natural emissions, occurring mainly as marine-dissolved sulphides from the oceans (7). From Vitevais et al. (8) we learn that 30-50% of the land surface has been transformed by human action; more nitrogen is now fixed synthetically and applied as fertilizers in agriculture than fixed naturally in all terrestrial ecosystems; the escape into the atmosphere of NO from fossil fuel and biomass combustion likewise is larger than the natural inputs, giving rise to photochemical ozone (“smog”) formation in extensive regions of the world; more than half of all accessible fresh water is used by man; mankind’s human activity has increased the species extinction rate by thousands to ten thousand fold in the tropical rain forests (9) and several climatically important “greenhouse” gases have substantially increased in the atmosphere: CO₂ by more than 30% and CH₄ by even more than 100%. Furthermore, mankind releases many toxic substances in the environment and even some, the chlorofluorocarbon gases, which are not toxic at all, but which nevertheless have led to the Antarctic “ozone hole” and which would have destroyed much of the ozone layer if no international regulatory measures to end their production had been taken. Coastal wetlands are also affected by humans, having resulted in the loss of 50% of the world’s mangroves. Finally, mechanized human predation (“fisheries”) removes more than 25% of the primary production of the oceans in the upwelling regions and 35% in the temperate continental shelf regions (10). Anthropic effects are also well illustrated by the history of biotic communities that leave remains in lake sediments. The effects documented include modification of the geochemical cycle in large freshwater systems and occur in systems remote from primary sources (11-13).

Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term “anthropocene” for the current geological epoch. The impacts of current human activities will continue over long periods. According to a study by Berger and Leopold (14), because of the anthropogenic emissions of CO₂, climate may depart significantly from natural behaviour over the next 50,000 years.

To assign a more specific date to the onset of the “anthropocene” seems somewhat arbitrary, but we propose the latter part of the 18th century, although we are aware that alternative proposals can be made (some may even want to include the entire holocene). However, we choose this date because, during the past two centuries, the global effects of human activities have become clearly noticeable. 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 CO₂ and CH₄ (7). Such a starting date also coincides with James Watt’s invention of the steam
Informe de citas: 1.127
(de Todas las bases de datos)

Buscó: Tema: (Anthropocene) ... Más

Este informe refleja las citas de los elementos origen indexados en todas las bases de datos.

Resultados encontrados: 1127
Total de veces citado (?): 10403
Total de veces citado sin citas propias (?): 8372
Artículos en que se cita (?): 7987
Artículos totales en que se cita sin citas propias (?): 7363
Promedio de citas por elemento (?): 9.23
h-index (?): 46
MAN AND NATURE;

or,

PHYSICAL GEOGRAPHY

AS MODIFIED BY HUMAN ACTION.

BY

GEORGE P. MARSH.

"Not all the winds, and storms, and earthquakes, and seas, and seasons of the world, have done so much to revolutionise the earth as Man, the power of an endless life, has done since the day he came forth upon it, and received dominion over it."—II. Samuel, chapter on the Power of an Endless Life.

NEW YORK:
CHARLES SCRIBNER, 124 GRAND STREET.
1864.
December 2015
Is the Anthropocene an issue of stratigraphy or pop culture?

Whitney J. Austin, Dept. of Earth Sciences, SUNY College at Brockport, Brockport, New York 14420, USA, whitney.austin@brockport.edu; and John M. Holbrook, School of Geology, Energy & the Environment, Texas Christian University, Fort Worth, Texas 76129, USA

THE ANTHROPOCENE DEBATE

The term Anthropocene recently entered into the rhetoric of both the scientific community and the popular environmental movement. Scientific proponents argue that global industrialization drives accelerated Earth-system changes unrivaled in Earth’s history. The discussion now filters into geological stratigraphy with proposals to amend formal time stratigraphic nomenclature (Zalasiewicz et al., 2008, 2010). Environmentalists suggest that terms like Anthropocene foster broad social and cultural awareness of human-induced environmental changes. Advocates argue that greater awareness of humanity’s role in environmental change encourages sustainable resource utilization.

Formal recognition of a new geologic epoch helps to broaden the scientific community’s discussion of humankind as a part of Earth-systems. Before the scientific community ventured too far, we wish to offer comment that considers the practicality of the Anthropocene to geological stratigraphy, the science to which it ultimately applies.

SUMMARY OF THE TERM ANTHROPOCENE

Crutzen and Steffen (2008) suggest that modern technology initiated the transformation of Earth-system behavior and altered environmental processes. They offer the term Anthropocene for the time interval dominated by human activities and indicate that the onset of the human ability to significantly shape Earth’s environment became notable with the Industrial Revolution. Steffen et al. (2011) argue that The Great Acceleration after World War II records a dramatic departure in monitored Earth processes from Holocene proxy trends. In contrast, Ruddiman (2005) infers that Holocene-scale anthropogenic greenhouse effects began when humans abandoned hunter-gatherer lifestyles for subsistence settlement, animal domestication, and cultivation agriculture.

The idea that humans interact with nature is not new, and philosophical ideologies about human responsibility permeate historical thinking (Hamilton, 2010; Steffen et al., 2011). Anthropocene offers a concept fundamentally different from many precursors. Present human society does not symbiotic relationship with nature. Humanity no natural processes, such as biogeochemical cycles, atmosphere transfers, and flux of surficial sediments (Zalasiewicz et al., 2011). Accelerated mass transfer of sediments (Williamson, 2015) has particular interest because of sediments.

Anthropocene: another academic invention?

Guido Visconti

READ

The time to anthropogenic bound concept has been and is still an important aspect of defining the Anthropocene and its epoch. Fang et al. (2017) have fully recognized the epoch as the time of anthropogenic climate change.

The “Anthropocene” epoch: Scientific decision or political statement?

GSA Today, v. 22, no. 7, doi: 10.1130/G3655W1,
<table>
<thead>
<tr>
<th>Chronology</th>
<th>Human influence through time</th>
<th>Selected major impacts on the biosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neogene</td>
<td></td>
<td>Human population exceeds 7 billion, 2011</td>
</tr>
<tr>
<td>Pliocene</td>
<td></td>
<td>Green revolution 1950s onwards</td>
</tr>
<tr>
<td>Miocene</td>
<td></td>
<td>Haber-Bosch process 1909</td>
</tr>
<tr>
<td>Pleistocene</td>
<td></td>
<td>Concentration of humans in huge cities 1900</td>
</tr>
<tr>
<td>Holocene</td>
<td></td>
<td>Gregor Mendel and genetics 1856</td>
</tr>
<tr>
<td>Anthropocene</td>
<td>1945?</td>
<td>Industrial scale use of fossil fuels 1709</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jethro Tull and mechanised farming 1701</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beginning of urbanisation 8 Kyr</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anthromes subsuming natural landscapes 10 Kyr</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Domestication of plants and animals ca 14 Kyr</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Culturally modern humans 70-50 Kyr</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anatomically modern humans 195 Kyr</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Human stone tools 2.5 Ma</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gradual increase of human influence</td>
</tr>
</tbody>
</table>

Complex, multi-tiered ecosystems: with no one species dominating production and consumption in the biosphere

(Williams, M. et al., 2016. Earth’s Future, 4, 1-20)
AD 1950s: Artificial radionuclides associated with atomic detonations
   (Zalasiewicz, Williams, Steffen, Crutzen 2010, radionuclides)

AD 1750-1800: The industrial revolution and global atmospheric change
   (Crutzen and Stoermer 2000, methane and carbon)

2,000 B.P. Alteration of the earth’s surface by human civilizations
   (Certini and Scalenghe 2011, anthropogenic soils)

5,000 – 4,000 B.P. Agriculture and Global Atmospheric Change
   (Fuller et al. 2011, methane from wet rice agriculture and cattle raising)

8,000-5,000 B.P. Agriculture and Global Atmospheric Change
   (Ruddiman and Thomson 2001, methane from wet rice agriculture)
   (Ruddiman 2003, carbon dioxide from forest clearance)

11,000-9,000 B.P. Emergence of significant human niche construction, Initial Domestication of plants and animals

11,700 B.P. Pleistocene – Holocene Boundary

~13,800 B.P. Megafaunal Predation and Vegetation Change
   (Doughty, Wolf, and Field 2010, birch pollen)

(Smith, B.D. & Zeder, M.A., 2013. Anthropocene, 4, 8-13)
Great Acceleration

Anthropocene

Palaeoanthropocene

“Global change”: humans’ influence on the environment

Non-anthropogenic Earth processes

atmospheric sciences

biogeochemistry

anthropology and archaeology

palaeoclimate

geology

Early hominids

Industrial revolution

Neolithic Revolution

(Foley, S.F. et al., 2013. Anthropocene, 3, 83-88)
ARCHAEOLOGY

Archaeologists Say the ‘Anthropocene’ Is Here—But It Began Long Ago

HONOLULU—A vocal group of geologists and other scientists are pushing to define a new geological epoch, marked by climatic and environmental change caused by humans. They’ve got a catchy name—the Anthropocene or “Age of Man”—plus an eponymous journal starting up this month and an international working group considering whether to make the designation official (Science, 7 October 2013, p. 32). At a session at the Society for American Archaeology meetings here, archaeologists argued that it’s high time for their field, which studies humans and their activities over geological time, to have a greater voice in the debate.

Most all the speakers at the standing-room-only session agreed that human impacts on the Earth are dramatic enough to merit a new epoch name—and that drawing attention to our changed relationship with the planet is a good idea. But all felt that such an epoch should start thousands of years ago. Rather than focusing on a relatively sudden planet-wide change—a line in a sedimentary deposit where one could plant a “golden spike” as is traditionally done to mark an epoch—the archaeologists outlined an unbroken chain of human influence stretching far back into prehistory. “Humans have been modifying ecosystems over a long period of time,” said archaeologist Bruce Smith of the Smithsonian Institution’s National Museum of Natural History (NMNH) in Washington, D.C. Such a view of the Anthropocene contrasts with that of most geologists and ecologists behind the movement, many of whom have

Heavy isotope landscape for thousands of years

sought a clear time marker for the “golden spike.” The most popular suggestion for a time point to end the recognized Holocene epoch, which began 11,700 years ago after the end of the last ice age, is the beginning of the Industrial Revolution about 1750 C.E., when manufacturing began to take hold and human-caused global warming is thought to have begun. Only then, proponents argue, did humans begin to change the chemistry of the atmosphere and oceans worldwide, alter the course of rivers, and transform the landscape, among other impacts. Others have suggested fallout from nuclear bombs as a distinctive Anthropocene signature.

But although the 23-member Working Group on the Anthropocene has no archaeologists or anthropologists, those fields also have horticultural data on major human impacts on the planet, said session chair Todd Braje, an archaeologist at Humboldt State University in Arcata, California. Those data show that humans began making global and large-scale transformations of the Earth long before the 18th century, panel members said.

Jon Erlandson, an archaeologist at the University of Oregon in Eugene, noted that people began transforming continents about 60,000 years ago, when our ancestors began to spread out from their ancestral home in Africa. That’s when large-scale hunting, burning vegetation, and cutting down forests, etc., began, and “set the stage for human domination of the earth,” Erlandson said.

Shortly after humans arrived in many regions, including most islands and several continents, many large mammals went extinct. Because the climate changed natur
The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?

We explore the development of the Anthropocene, the current epoch in which humans and our societies have become a global geophysical force. The Anthropocene began around 1800 with the onset of industrialization, the central feature of which was the enormous expansion in the use of fossil fuels. We use atmospheric carbon dioxide concentration as a single, simple indicator to track the progression of the Anthropocene. From a preindustrial value of 270–275 ppm, atmospheric carbon dioxide had risen to about 310 ppm by 1950. Since then the human enterprise has experienced a remarkable expansion, the Great Acceleration, with significant consequences for Earth System functioning. Atmospheric CO₂ concentration has risen from 310 to 380 ppm since 1950, with about half of the total rise since the preindustrial era occurring in just the last 30 years. The Great Acceleration is reaching criticality. Whatever unfolds, the net few decades will surely be a tipping point in the evolution of the Anthropocene.

INTRODUCTION

Global warming and many other human-driven changes to the environment are raising concerns about the future of Earth’s environment and its ability to provide the services required to sustain human civilizations. The consequences of this unintended experiment of humankind on its own life support system are hotly debated, but worst-case scenarios paint a gloomy picture for the future of contemporary societies.

Underlying global change (Box 1) are human-driven alterations of (i) the biological fabric of the Earth; (ii) the stocks and flows of major elements in the planetary machinery such as nitrogen, carbon, phosphorus, and silicon; and (iii) the energy balance at the Earth’s surface (2). The term Anthropocene (Box 2) suggests that the Earth has now left its natural geological epoch, the present interglacial state called the Holocene. Human activities have become so pervasive and profound that they rival the great forces of Nature and are pushing the Earth into planetary terra incognita. The Earth is rapidly moving into a less biologically diverse, less forested, much warmer, and probably wetter and stormier state.

The phenomena of global change represent a profound shift in the relationship between humans and the rest of nature. Interest in this fundamental issue has escalated rapidly in the international research community, leading to innovative new research projects like Integrated History and future of People on Earth (IHOP-E) (3). The objective of this paper is to explore one aspect of the IHOP-E research agenda—the evolution of humans and our societies from hunter-gatherers to a global geophysical force.

To address this objective, we examine the trajectory of the human enterprise through time, from the arrival of humans on Earth through the present and into the next centuries. Our analysis is based on a few critical questions:

- Is the imprint of human activity on the environment discernible at the global scale? How has this imprint evolved through time?
- How does the magnitude and rate of human impact compare with the natural variability of the Earth’s environment? Are human effects similar to or greater than the great forces of nature in terms of their influence on Earth System functioning?
- What are the socioeconomic, cultural, political, and technological developments that change the relationship between human societies and the rest of nature and lead to accelerating impacts on the Earth System?

Pre-Anthropocene

Before the advent of humans, food in centuries, under often thought harmony with the environment and a radical change in human impact on the environment.

The mystery of Homo erectus is that Homo erectus was not very different from Homo sapiens. Homo erectus, as a matter of fact, was the first great migration of humans from Africa to the rest of the world. The migration of Homo erectus was a radical change in human impact on the environment and the emergence of new human societies and cultures.
(Steffen, W. et al., 2015. The Anthropocene Review, 2, 81-98)
Affluence measured by world GDP*  
55 trillion USD

Population worldwide
7 billion

Technology patent applications
1.9 million

1900

1950

2011

(Steffen, W. et al., 2011. Ambio, 40, 739-761)
Current state of the Earth System (2016)

Great Acceleration

c.1950

Human pressures: early agriculture; industrial revolution

Typical Holocene variability

Holocene envelope of natural variability

Holocene basin of attraction

(Steffen, W. et al., 2016. Earth’s Future)
When did the Anthropocene begin? A mid-twentieth century boundary level is stratigraphically optimal

Jan Zalasiewicz b, Colin N. Waters a,*, Mark Williams a, Anthony D. Barnosky a, Alejandro Carrega c, Paul Crutzen b, Erle Ellis b, Michael A. Ellis c, Ian J. Fairchild a, Jacques Grineval d, Peter K. Haff e, Irla Hajdas f, Reinhold Leinfelder g, John McNeill h, Eric O. Odada k, Clément Potier l, Daniel Richter m, Willy Steffen m, Colin Summerhayes m, James P.M. Spivs i, Davao Vidas j, Michael Wagreich f, Scott L. Wing n, Alexander P. Wolfe f, An Zhisheng o, Naomi Oreskes a

a Department of Geology, University of Leicester, University Road, Leicester LE1 7RH, UK
b Geological Survey of Canada, 255 Douglas Street, Ottawa, ON K1A 0E8, Canada
c Department of History and Philosophy of Science, University of Cambridge, Downing Street, Cambridge CB2 3QG, UK
d School of Geography, Earth and Environment, University of Leeds, LS2 9JT, UK
e Institute for Marine and Coastal Studies, University of New South Wales, Sydney, NSW 2052, Australia
f Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China g Institute of Geology, University of Oslo, Norway
h Department of Food Science, Stockholm University, Stockholm, Sweden i Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, BC V6T 1Z4, Canada
j School of Earth and Environment, University of Leeds, LS2 9JT, UK
k Institute of Marine and Coastal Studies, University of New South Wales, Sydney, NSW 2052, Australia
l Department of History and Philosophy of Science, University of Cambridge, Downing Street, Cambridge CB2 3QG, UK
m Department of Geography, University of Oxford, Oxford, UK
n Department of Geography, University of Michigan, Ann Arbor, MI 48109, USA
o Department of Geology, University of Nijmegen, Nijmegen, The Netherlands

Abstract
Many scientists are making the case that humanity is living in a new geological epoch, the Anthropocene, but there is no agreement yet as to when this epoch began. The start might be defined by a historical event, such as the beginning of the fossil-fueled Industrial Revolution or the first nuclear explosion in 1945. Standard stratigraphic practice, however, requires a more significant, globally widespread, and abrupt signature, and the fallout from nuclear weapons testing appears most suitable. The appearance of plutonium 239 (used in post-1945 above-ground nuclear weapons tests) makes a good marker: This isotope is rare in nature but a significant component of fallout. It has other features to recommend it as a stable marker in layers of sedimentary rock and soil, including long half-life, low solubility, and high particle reactivity. It may be used in conjunction with other radioactive isotopes, such as americium 241 and carbon 14, to categorize distinct fallout signatures in sediments and ice caps. On a global scale, the first appearance of plutonium 239 in sedimentary sequences corresponds to the early 1950s. While plutonium is easily detectable over the entire Earth using modern measurement techniques, a site to define the Anthropocene (known as a “golden spike”) would ideally be located between 30 and 60 degrees north of the equator, where fallout is maximal, within undisturbed marine or lake environments.

Keywords
Anthropocene, golden spike, nuclear weapons fallout, radioactive isotope, radiogenic signature; Trinity test

ARTICLE INFO
Article history:
Available online 12 January 2015

Keywords
Anthropocene
Stratigraphy
GSP
GSA

R E F E R E N C E S

Can nuclear weapons fallout mark the beginning of the Anthropocene Epoch?

Colin N. Waters, James P. M. Syvitski, Agnieszka Gałuszka, Gary J. Hancock, Jan Zalasiewicz, Alejandro Carrega, Jacques Leifeld, Catherine Jandel, J. R. McNeill, Colin Summerhayes, and Anthony Barnosky

Seventy years ago—on 16 July 1945—the world’s first nuclear device exploded at the Trinity Test Site in what was then the Alamogordo Bombing and Gunnery Range in New Mexico. After an intense flash of light and heat, and a roaring shock wave that took 40 seconds to reach the closest observers, a fireball rose into the sky, forming a mushroom cloud 75 miles high. J. Robert Oppenheimer later wrote that he and other Manhattan Project scientists could see a “horrifying beauty” in the nuclear explosion that had taken place.
The world's first atomic explosion occurred on July 16, 1945, at the Trinity Site near the north end of the historic Jornada del Muerto. It marked the beginning of the nuclear age, and the culmination of the Manhattan Project. The site, now part of the White Sands Missile Range, is closed to the public.
(Waters, C.N. et al., 2016. Science, 351 (6269), aad2622-1/10)
A stratigraphical basis for the Anthropocene

COLIN N. WATERS1,*, JAN A. ZALASIEWICZ2, MARK WILLIAMS2, MICHAEL A. ELLIS1 & ANDREA M. SNELLING3
1Environmental Science Centre, British Geological Survey, Keyworth, Nottingham NG12 5GG, UK
2Department of Geology, University of Leicester, Leicester LE1 7RH, UK
3NERC Isotope Geosciences Laboratory, British Geological Survey, Keyworth, Nottingham NG12 5GG, UK
*Corresponding author (e-mail: cnw@bgs.ac.uk)

Abstract: Recognition of intimate feedback mechanisms linking changes across the atmosphere, biosphere, geosphere and hydrosphere demonstrates the pervasive nature of human kind’s influence, perhaps to the point that we have fashioned a new geological epoch, the Anthropocene. How will these changes be evident as long-lasting signatures in the geological record? To establish the Anthropocene as a formal chronostratigraphical unit it is necessary to consider a spectrum of indicators of anthropogenically induced environmental change, and to determine how these show as stratigraphic signals that can be used to characterize an Anthropocene unit and to recognize its base. It is important to consider these signals against a context of Holocene and earlier stratigraphical patterns. Here we review the parameters used by stratigraphers to identify chronostratigraphical units and how these could apply to the definition of the Anthropocene. The onset of the range of signatures is diachronous, although many show maximum signatures which post-date 1985, leading to the suggestion that this date may be a suitable age for the start of the Anthropocene.

The ‘Anthropocene’ is in many respects a novel potential geological unit. Stratigraphy, which deals with the classification of geological time (geochronology) and material time-rock units (chronostratigraphy), has historically defined geological units based upon significant, but temporally distant, events. These events are typically, although not exclusively, associated with major changes in the fossil contents of rocks below and above a particular horizon, and therefore with the temporal distribution of life forms. It was only following such observations that new stratigraphical units were proposed and ultimately defined. For example, J. Phillips used the major mass extinction at the end of the Permian in 1840 to recognize the beginning of both the Triassic Period and of the Mesozoic Era. The ultimate definition of the base of the Triassic, however, was accomplished only in 2001, when the Global Stratotype Section and Point (GSSP) was taken at the base of a specific bed in a section in Melsun, China, coinciding with the lowest occurrence of the primary marker, the conodont Hindeodus parvus (Yin et al. 2001). In contrast, the Anthropocene was proposed as a term (Crutzen & Stoermer 2000) before any consideration of the nature of the signature of this new stratigraphical unit was given. For the first time in geological history, humanity has been able to observe and be part of the processes that potentially may signal such a change from the preceding to succeeding epoch.

What are the key ‘events’ over the last decades to millennia that have the potential to leave a recognizable record in sediments/sediments that could be used to define the base of the Anthropocene? The options cover a diverse range of geoscientific fields and need not be restricted to the chronostratigraphical tools typically used throughout much of the geological column to define chronostratigraphical units. Potential stratigraphical tools and techniques that may be used to define the base of the Anthropocene include the following (Fig. 1):

1. Appearance and increased abundance of anthropogenic deposits:
   • artificial anthropogenic deposits;
   • anthropogenic soils (anthrosols);
   • novel minerals and mineraloids;
   • anthropogenic subsurface structures (‘trace fossils’);
   • anthropogenic modification of terrestrial and marine sedimentary systems.

2. Biotic turnover:
   • megafauna;
   • reef ecosystems;
   • microflora;
   • microfauna.

Research article

The technofossil record of humans

Jan Zalasiewicz, 1 Mark Williams, 1 Colin N Waters, 2 Anthony D Barnosky 1,4,5 and Peter Haff 6

Abstract

As humans have colonised and modified the Earth’s surface, they have developed progressively more sophisticated tools and technologies. These underpin a new kind of stratigraphy, that we term technostratigraphy, marked by the geologically accelerated evolution and diversification of technofossils – the preservable material remains of the technosphere (Haff, 2013), driven by human purpose and transmitted cultural memory, and with the dynamics of an emergent system. The technosphere, present in some form for most of the Quaternary, shows several thresholds. Its expansion and transcontinental synchronisation in the mid 20th century has produced a global technostratigraphy that combines very high time-resolution, great geometrical complexity and wide (including transplanetary) extent. Technostratigraphy can help characterise the deposits of a potential Anthropocene Epoch and its emergence marks a step change in planetary mode.

Keywords

Anthropocene, human artefacts, stratigraphy, technology

Introduction

From the beginnings of geology, fossils have been recognised as central to the science, not only because they are a record of life (the most important feature of our planet) but because biological evolution has provided a means of dating and correlating strata, and hence underpinning the Geological Time Scale. Thus, the Phanerozoic Eon (roughly, the last half-billion years of Earth history) was characterised by complex metazoans with hard skeletal parts. It has a finely resolved timescale largely founded on fossil zones, reflecting the evolution of these organisms. In this way, Phanerozoic time can be split into intervals that may be less than 1 million years in duration, for

1University of Leicester, UK
2British Geological Survey, UK
3University of California, USA
4University of California Museum of Paleontology, USA
5University of California Museum of Vertebrate Zoology, USA
6Duke University, USA

Corresponding author: Jan Zalasiewicz, Department of Geology, University of Leicester, University Road, Leicester LE1 7RH, UK. Email: jzl1@e.ac.uk

The Anthropocene Review
2014, Vol. 1(1) 34-43
© The Author(s) 2014
Reprints and permissions:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/2053013314533190
szr.sagepub.com

$SAGE$
The Anthropocene is functionally and stratigraphically distinct from the Holocene


Human activity is leaving a pervasive and persistent signature on Earth. Vigorous debate continues about whether this warrants a recognition as a new geologic time unit known as the Anthropocene. We review anthropogenic markers of functional changes in the Earth system through the stratigraphic record. The appearance of manufactured materials in sediments, including aluminum, plastics, and concrete, coincides with global spikes in fallout radionuclides and particulates from fossil fuel combustion. Carbon, nitrogen, and phosphorus cycles have been substantially modified over the past century. Rates of sea-level rise and the extent of human perturbation of the climate system exceed Late Holocene changes. Biotic changes include species invasions worldwide and accelerating rates of extinction. These combined signals render the Anthropocene stratigraphically distinct from the Holocene and earlier epochs.

The term "Anthropocene" is currently used informally to encompass different geological, ecological, sociological, and anthropological changes in recent Earth history. The origins of the concept of the Anthropocene, its terminology, and its sociopolitical implications are widely discussed (2, 3). When considering the stratigraphic definition of the Anthropocene, there are two basic questions: Have humans changed the Earth system to such an extent that recent and currently forming geological deposits include a signature that is distinct from those of the Holocene and earlier epochs, which will rejoin in the geological record? If so, when did this stratigraphic signal (not necessarily the first detectable anthropogenic change) become recognizable worldwide? These questions are considered here in the context of how stratigraphic units have been formally recognized earlier in the Quaternary period.

Proposals for marking the start of the Anthropocene have included (i) an "early Anthropocene" associated with the advent of agriculture, animal domestication, extensive deforestation, and gradual increases in atmospheric carbon dioxide (CO2) and methane (CH4) levels thousands of years ago (4, 5) (ii) the Holocene Exchange of Old and New World species associated with coloni-

The Quaternary period, which begins 2.56 million years ago (Ma), is subdivided into geological time units (epochs and ages) with boundaries that are dated at least in part to climate change events expressed as marine isotopic stages. In association with palaeomagnetic reversals (6), this contrasts with the subdivision of most of the Phanerozoic eon (the past ~541 to 1 Ma), for which the first or last appearance of key fossil taxa is typically used to define time units. Fossil-based boundaries represent change at rates too slow and time-transgressive for the geologically recent past, in which the time units are of comparatively short duration (about 13,000 years for the Holocene versus 2 million years or more for earlier epochs). These time intervals are recognizable in the geologic record as chronostratigraphic units (epochs and ages), which, in contrast to the time units, are physical entities, including rocks, sediments, and glacier ice. Ideally, a chronostratigraphic unit is exemplified, and its lower boundary defined, as a single locality termed the Global Boundary Stratotype Section and Point (GSSP), which is typically in marine strata for pre-Holocene series (7).

The start of the Holocene epoch (or series) is based on the termination of the transition from the last glacial phase into an interval of warming accompanied by -120 to 130 ka of sea-level rise. The warming took place over about 10,000 years and is recorded by a variety of stratigraphic signals that are not all globally synchronous. In the Northern Hemisphere, the signal for the Holocene's beginning...
(Waters, C.N. et al., 2016. Science, 351 (6269), aad2622-1/10)
(Waters, C.N. et al., 2016. Science, 351 (6269), aad2622-1/10)
<table>
<thead>
<tr>
<th>Material</th>
<th>1800</th>
<th>1850</th>
<th>1900</th>
<th>1950</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gutta percha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parkesine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Celluloid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shellac gramophone records</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscose silk/rayon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bakelite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scotch tape</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinyl LPs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyethylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nylon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellulose acetate cigarette filters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVC water pipes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial polystyrene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDPE bottles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velcro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic credit cards</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polythene bags</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial polyester fibres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expanded polystyrene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polypropylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polycarbonates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lego</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PET bottles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>uPVC windows</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compact discs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Zalasiewicz, J. et al., 2016. Anthropocene)
(Head, M.J. et al., 2015. Quaternary International, 383, 1-3)
Mesolithic shell midden, El Mazo (Asturias)
8000-6700 yr BP
ORIGEN DE LA AGRICULTURA EN EL PAÍS VASCO Y TRANSFORMACIONES EN EL PAISAJE: ANÁLISIS DE RESTOS VEGETALES ARQUEOLÓGICOS

2002 Lydia ZAPATA PEÑA
Roman harbour of Oiasso
<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>DI</th>
<th>Lithology</th>
<th>No. of species</th>
<th>Allochthonous (%)</th>
<th>Species abundance (%)</th>
<th>Pb (mg kg⁻¹)</th>
<th>Zn (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-21</td>
<td></td>
<td></td>
<td>5 15 25 20 40 60 80</td>
<td>1 2 3 4 5 6 7 8</td>
<td>100 300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-20</td>
<td></td>
<td>Fill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- brackish marsh
- fluviatile
- saline intertidal
- marine advance

(Pleistocene fluviatile)

Tunelboca beach
(Irabien, M.J. et al., 2015. Quaternary International, 364, 196-205)
since 1960s

since 1980s

Zumaia 1 core

>1900 CE

Figura 9: Esferoide carbonáceo

Figura 10: Esferoide polimérico

Figura 11: Esferoide metálico

(Goffard, A., 2015. CKQ, 6, 43-60)
Urdiaibai estuary
1957 (since beginning of 19th century)
Isla core

Isla saltmarsh
Isla core

Thank you!