The Anthropocene

Alejandro Cearreta
(UPV/EHU, Anthropocene Working Group)
Cenozoic Era

Phanerozoic Eon

Quaternary Period

Last climate cycle

Holocene Epoch

(Steffen, W. et al., 2016. Earth’s Future, 4, 324-345)
EARTH’S GREAT SERVICE TO HUMANKIND

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

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 1833, and adopted by the International Geological Congress in Bologna in 1885 (1). During the Holocene mankind’s activities gradually grew into a significant geological, morphological force, as recognised early on by a number of scientists. Thus, G.F. Marsh already in 1864 published a book with the title “Man and Nature”, more recently referred to as “The Earth as Modified by Human Action” (2). Stoppani in 1873 rated mankind’s activities as a “new tectonic force which in power and universality may be compared to the greater forces of nature” (3). From Clark (4), Stoppani already spoke of the “anthropocenic era. Mankind has now inhabited or visited almost all places on Earth; he has even set foot on the moon.” The great Russian geologist V.I. Vernadsky (5) 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. LeRoy in 1948 coined the term “zoosphere”, the world of thought, to mark the growing role played by mankind’s intellectual 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 e.g. by a growth in cattle population to 1400 million (6) (about one cow per average size family). Urbanisation has even increased tenfold in the past century. In a few generations mankind is degrading 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 dimethyl-sulphide from the oceans (7) from Völkens 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 mankind; human activity has increased the species extinction rate by thousand to ten thousand fold in the tropical rain forests (9) and several climatically important “greenhouse” gases have substantially increased (10) (11) with 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 (“fishing”) removes more than 25% of the primary production of the oceans in the upwelling regions and 35% in the temperate continental shelf regions (10). Anthropogenic effects are also well illustrated by the history of biotic communities that leave remains in lake sediments. The effects documented include modification of the geochronological 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 Loutre (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
Total Publications: 2,747

- h-index: 69
- Average citations per item: 9.77
- Sum of Times Cited: 26,838
- Without self citations: 20,707
- Citing articles: 18,875
- Without self citations: 17,256
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 revolutionize 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."—H. Newman, sermon on the Power of an Infinite Life.

NEW YORK:

CHARLES SCRIBNER, 124 GRAND STREET.

1873.
Welcome to the Anthropocene

Geology's new age
Anthropocene Working Group (since 2009)
Is the Anthropocene an issue of stratigraphy or pop culture?

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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 the broader scientific community solidify the idea of humanity as an Earth-system driver. 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 (2006) 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 ideas 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 have a symbiotic relationship with nature. Humanity no longer manipulates natural processes, such as biogeochemical cycles, atmosphere transfers, and flux of surficial sediments (e.g., 2011). Accelerated mass transfer of sediments (e.g., Wilkinson, 2005) has particular interest because sedimentary processes are not simply continuous but also episodic.

Anthropocene: another academic invention?

Guido Visconti

GSA Today, v. 22, n. 7, doi: 10.1130/G35194.1

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

Introduction

The idea of Anthropocene was introduced by Crutzen and Steffen (2006) in a paper in the Global Change Biology of the IGBP in May 2000. The idea was somewhat refined as a concept in a one-page article in Nature in 2002 (Crutzen 2002). Since then, the Anthropocene has been the subject of papers, meetings, and debate and discussion at the scientific, political, and philosophical levels. The Anthropocene should define a new Epoch of the Quaternary Period and appear as a new Epoch of geological time, which could help to redefine the time frame of human history and to better understand the effect of human behavior on the planet.

The initial response to the idea came mainly from Europe. Recently, Austin and Holbrook (2012) observed that the main problem was that the proposed Anthropocene is not consistent with the practice of stratigraphy. After even if the manifestations of the human influence on landscape are widespread, they are confined only to the few meters of depth primarily to soils. The Anthropocene issue seems to be the most important as used recently by Finney (2013) and Cohen et al. (2013), who raises a number of issues that must be addressed by the stratigraphic community. They refer to the Anthropocene being a unit of Earth history or human history that is like a projection into the future. This point stresses that since the last millennium human observations are more complete and refined will be used to study the March 2014 issue of Radiolaria with the papers presented at the conference: Anthropocene: natural and man-made conditions of the Earth’s fragile equilibrium held steady. Rome, November 26-27, 2012.
<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>Quaternary</td>
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<td>Anthropocene</td>
<td>Human migration</td>
<td>Human population exceeds 7 billion, 2011</td>
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<td>Modern human behaviour</td>
<td>Green revolution 1950s onwards</td>
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<tr>
<td>Holocene</td>
<td>Forest clearing and farming</td>
<td>Haber-Bosch process 1909</td>
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<tr>
<td>0.0118 Ma</td>
<td>Industrialization</td>
<td>Concentration of humans in huge cities 1900</td>
</tr>
<tr>
<td>Pleistocene</td>
<td>Population growth</td>
<td>Gregor Mendel and genetics 1856</td>
</tr>
<tr>
<td>2.588 Ma</td>
<td></td>
<td>Industrial scale use of fossil fuels 1709</td>
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<tr>
<td>Neogene</td>
<td></td>
<td>Jethro Tull and mechanised farming 1701</td>
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<tr>
<td>Pliocene</td>
<td></td>
<td>Beginning of urbanisation 8 Kyr</td>
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<tr>
<td>5.333 Ma</td>
<td></td>
<td>Anthromes subsuming natural landscapes 10 Kyr</td>
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<tr>
<td>Miocene</td>
<td></td>
<td>Domestication of plants and animals ca 14 Kyr</td>
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<td></td>
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<td>Culturally modern humans 70-50 Kyr</td>
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<td></td>
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<td>Anatomically modern humans 195 Kyr</td>
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<td>Gradual increase of human influence</td>
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</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)
Great Acceleration

Anthropocene

Palaeoanthropocene

Effect of humans on the environment

Atmospheric sciences

Biogeochemistry

Anthropology and archaeology

Palaeoclimate

Geology

“Global change”: humans’ influence on the environment

Industrial revolution

Neolithic Revolution

Early hominids

Non-anthropogenic Earth processes

1 day

1 year

100 years

10,000 years

1 myr

100 myr

4,567 m.yr

(Foley, S.F. et al., 2013. Anthropocene, 3, 83-88)
Socio-economic trends

- Population
- Real GDP
- Foreign direct investment

Earth system trends

- Carbon dioxide
- Nitrous oxide
- Methane
- Urban population
- Primary energy use
- Fertilizer consumption

- Stratospheric ozone
- Surface temperature
- Ocean acidification

- Large dams
- Water use
- Paper production

- Marine fish capture
- Shrimp aquaculture
- Nitrogen to coastal zone

- Transportation
- Telecommunications
- International tourism

- Tropical forest loss
- Domesticated land
- Terrestrial biosphere degradation

(Steffen, W. et al., 2015. The Anthropocene Review, 2, 81-98)
(Steffen, W. et al., 2016. Earth’s Future, 4, 324-345)
The technofossil record of humans

Jan Zalasiewicz,1 Mark Williams,1 Colin N Waters,2 Anthony D Barnosky1,4,5 and Peter Haff6

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 transcultural 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
When did the Anthropocene begin? A mid-twentieth century boundary level is stratigraphically optimal


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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 1940s. 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, radiocarbon isotope, radiogenic signature, Trinity test

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

Colin N. Waters, James P. M. Syvitski, Agnieszka Galuszka, Gary J. Hancock, Jan Zalasiewicz, Alejandro Cearrera, Jacques Grinevald, Catherine Jeandel, J. R. McNeill, Colin Summerhayes, and Anthony Barnosky

Seventy years ago—on July 16, 1945—the world’s first nuclear device exploded at the Trinity Test Site in what was then the Alamogordo Bombing and Gunny 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 said that he and other Manhattan Project scientists had been “enlisted” in a scientific experiment.
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)
Source: UNSCEAR (2000)

Cumulative anthropogenic aluminum (Tg) and concrete production (1000 Tg)

- Aluminum
- Concrete
- Plastics
- Synthetic fibers

Year (CE)

Global annual plastics production (Tg) and synthetic fiber production (Gg)

Great Acceleration

1900 1920 1940 1960 1980 2000

(Waters, C.N. et al., 2016. Science, 351 (6269), aad2622-1/10)
World plastic production (Mt/тонne)

Material
- Gutta percha
- Parkesine
- Celluloid
- Shellac gramophone records
- Viscose silk/rayon
- Bakelite
- Scotch tape
- Vinyl LPs
- Polyethylene
- Nylon
- Cellulose acetate cigarette filters
- PVC water pipes
- Commercial polystyrene
- LDPE bottles
- Formica
- Velcro
- Plastic credit cards
- Polythene bags
- Commercial polyester fibres
- Expanded polystyrene
- Polypropylene
- Polycarbonates
- Lego
- PET bottles
- uPVC windows
- Compact discs

(Zalasiewicz, J. et al., 2016. Anthropocene, 13, 4-17)
Extinctions

Cumulative extinctions as % of species

Year (CE)

1500-1600  1600-1700  1700-1800  1800-1900  1900-2010

Mammals
Birds
All vertebrates
Fish, reptiles & amphibians
Background

(Waters, C.N. et al., 2016. Science, 351 (6269), aad2622-1/10)
<table>
<thead>
<tr>
<th>Phanerozoic</th>
<th>Cenozoic</th>
<th>Quaternary</th>
<th>Series / Epoch</th>
<th>Subseries / Subepoch</th>
<th>Stage / Age</th>
<th>GSSP</th>
<th>Numerical age (Ma)</th>
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<td></td>
<td></td>
<td>Holocene</td>
<td>U/L</td>
<td>Meghalayan</td>
<td>present</td>
<td></td>
<td>mid-20th century</td>
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<td>M</td>
<td>Northgrippian</td>
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<td>L/E</td>
<td>Greenlandian</td>
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<td>Pleistocene</td>
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<td>L/E</td>
<td>Calabrian</td>
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<td>Gelasian</td>
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<td>2.58</td>
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(Zelasiewicz, J. et al., 2017. Anthropocene, 19, 55-60)
Bilbao estuary
Geological map 1877
Barakaldo 1976
Zorroza 1970s
Abra bay in 1970s
Abra bay (Getxo)
Core extraction Abra 1 core
since 2010 CE

Tunelboca beach (Getxo)

Eocene rocks (45 My)

Anthropocene rocks (iron slags)
30 million tonnes
1902-1995 CE

AHV blast furnaces

(Goitia, J., 2012. Unpublished MSc dissertation UPV/EHU)
1 million tonnes since 1940s
Technofossils (refractory bricks)
Technofossils (plastics)
Zumaia 1 core

Depth (cm) Metals (ppm) Year CE

Foraminifera 100 g\(^{-1}\)
- Cu
- Ni
- Pb
- Zn

Polymeric spheroids from 1980s

Iron spheroids from 1960s

Carbonaceous spheroids from 1900s

(Waters, C.N. et al., 2018. Earth-Science Reviews, 178, 379-429)
Thank you!

LESSONS FROM THE FOSSIL RECORD

21st century AD
A layer of consumer goods marks the point above which humans are very rare.
The cause of the consumer goods layer is implicated in the demise of the humans

65 million years BC
A layer of iridium in the rock strata marks the point above which dinosaur fossils are very rare.
The cause of the iridium layer is implicated in the demise of the dinosaurs