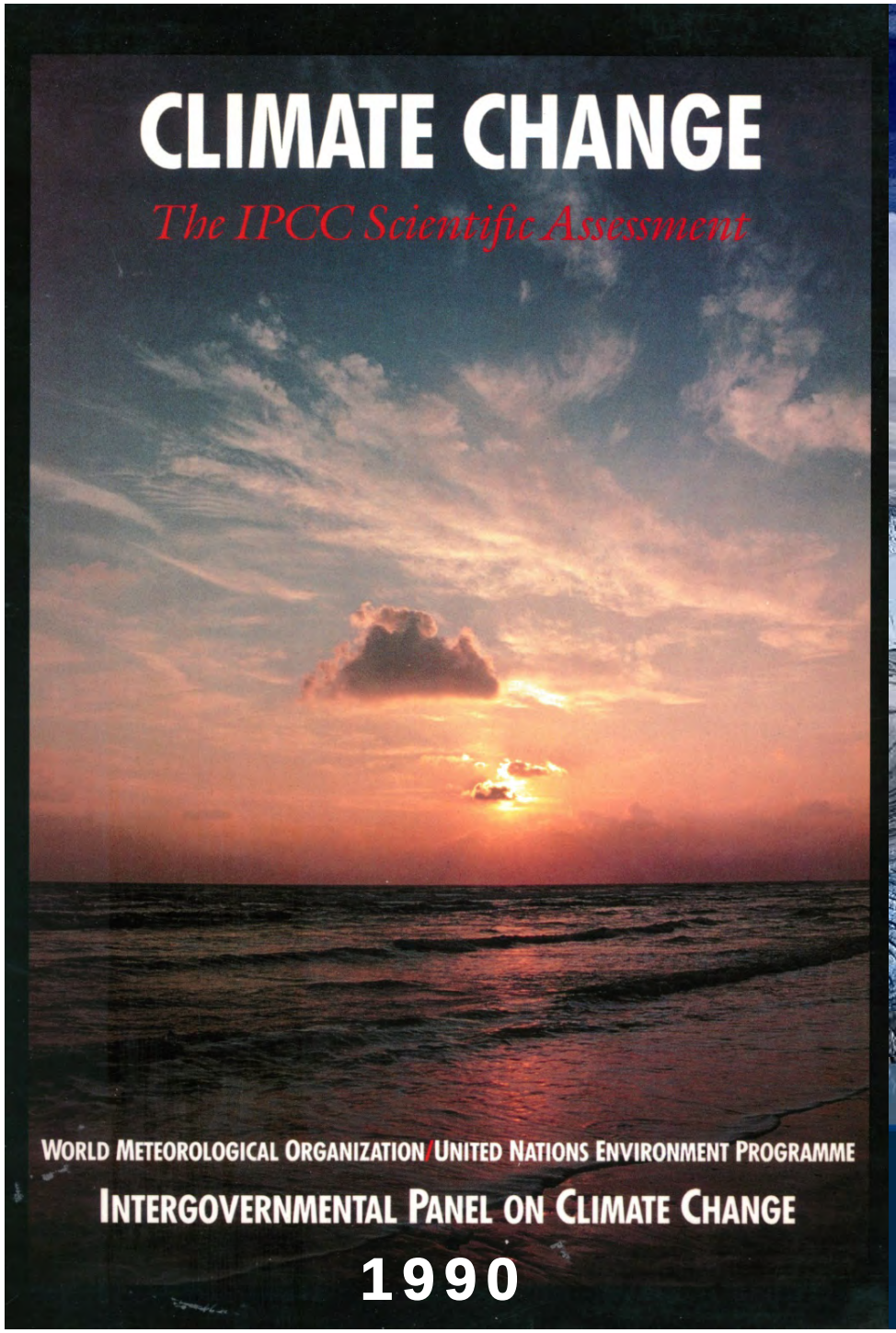
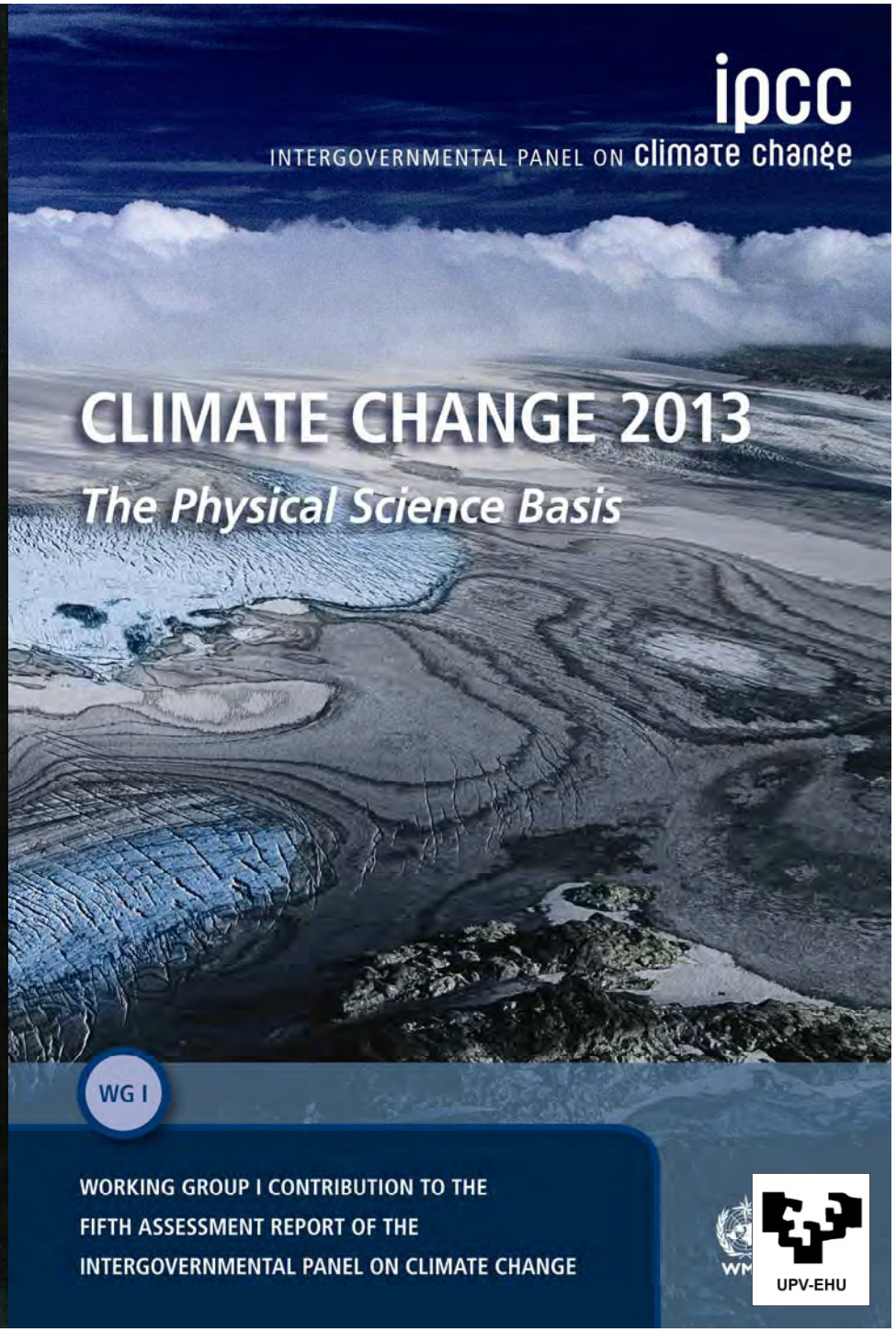
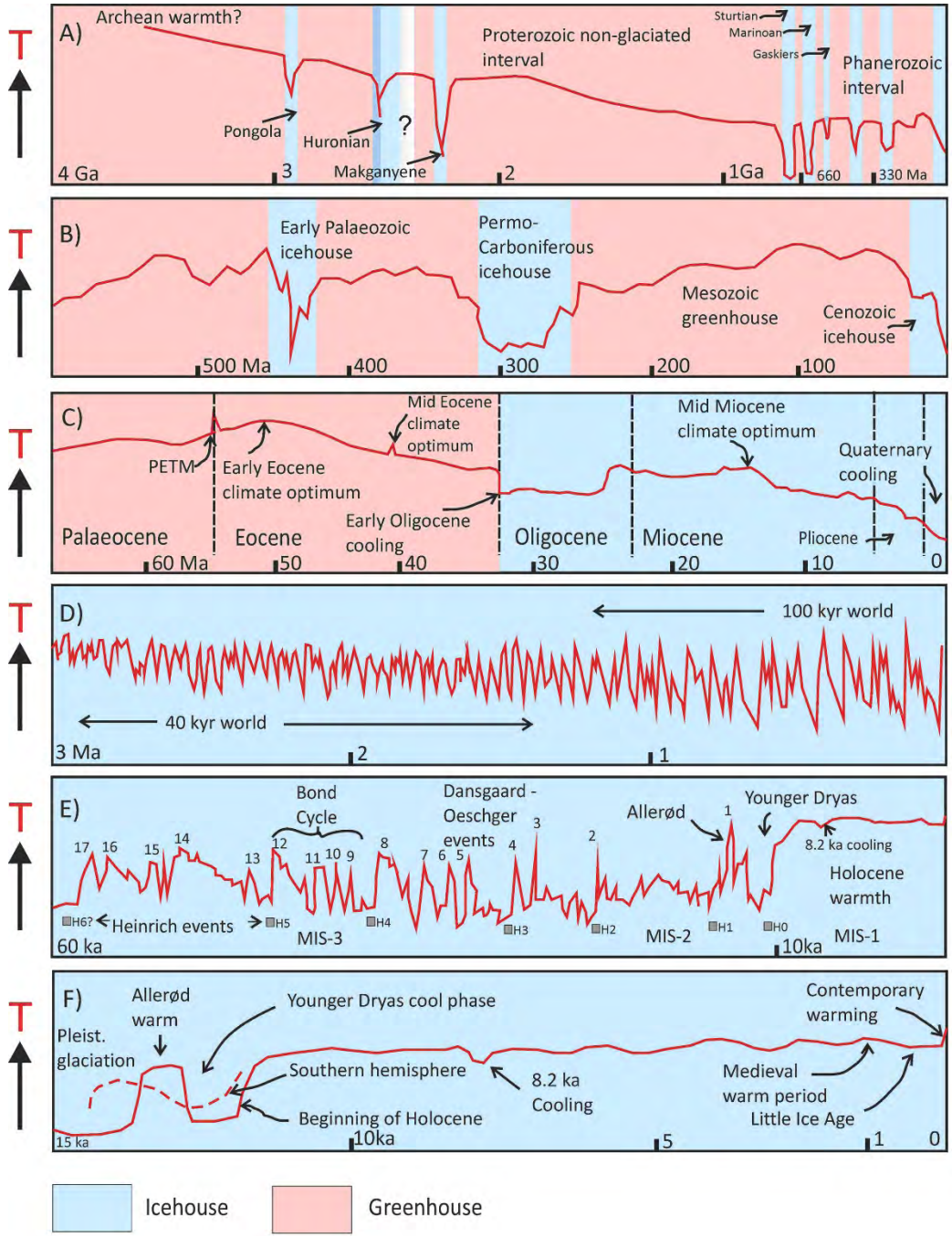
The Anthropocene

Alejandro Cearreta
(UPV/EHU, Anthropocene Working Group)


CLIMATE CHANGE
The IPCC Scientific Assessment
WORLD METEOROLOGICAL ORGANIZATION/UNITED NATIONS ENVIRONMENT PROGRAMME
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
1990


ipcc
INTERGOVERNMENTAL PANEL ON climate change
CLIMATE CHANGE 2013
The Physical Science Basis
WG I
WORKING GROUP I CONTRIBUTION TO THE
FIFTH ASSESSMENT REPORT OF THE
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
UPV-EHU



(Steffen, W. et al., 2016. Earth's Future, 4, 324-345)

Geological history

Phanerozoic Eon

Cenozoic Era

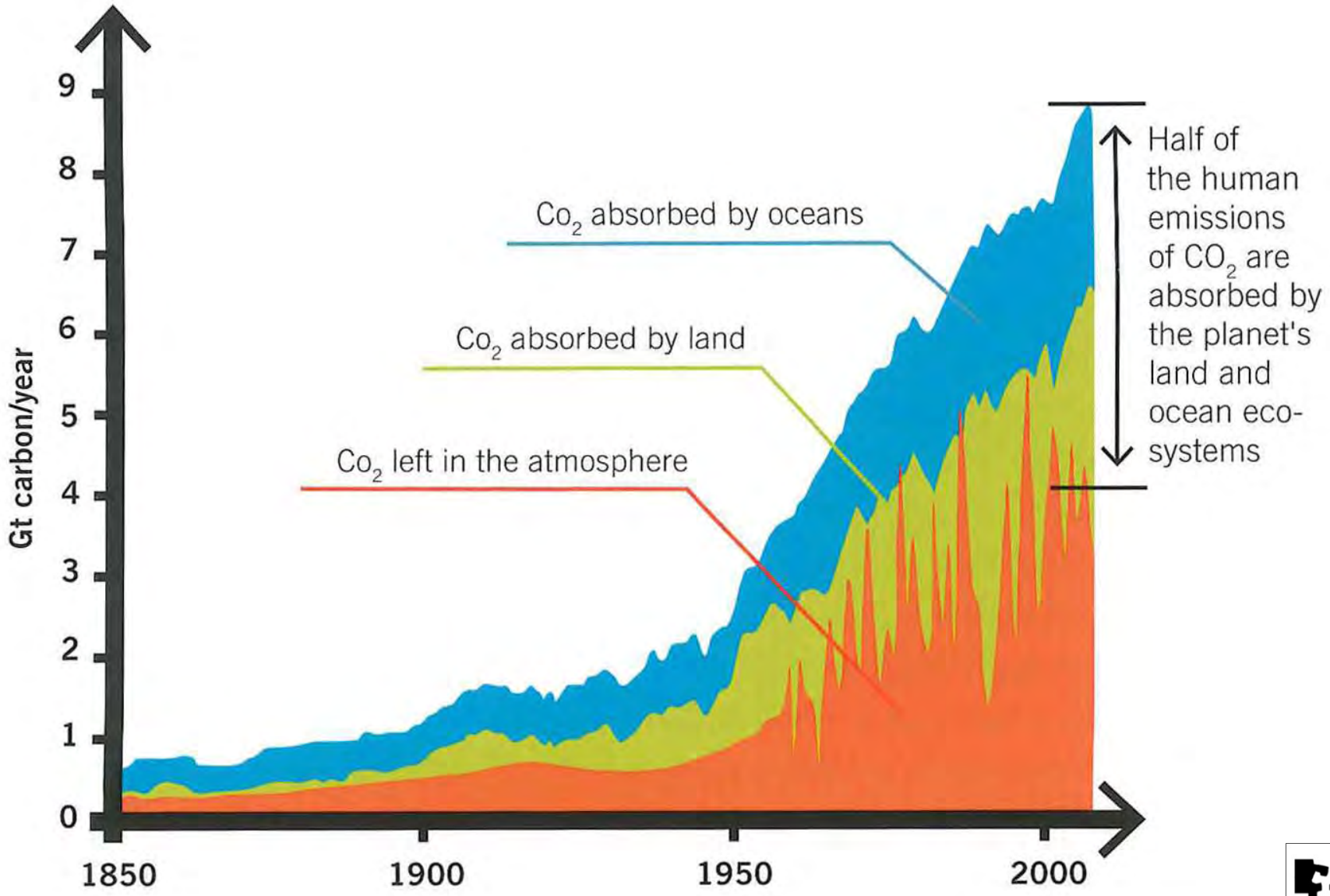
Quaternary Period

Last climate cycle

Holocene Epoch

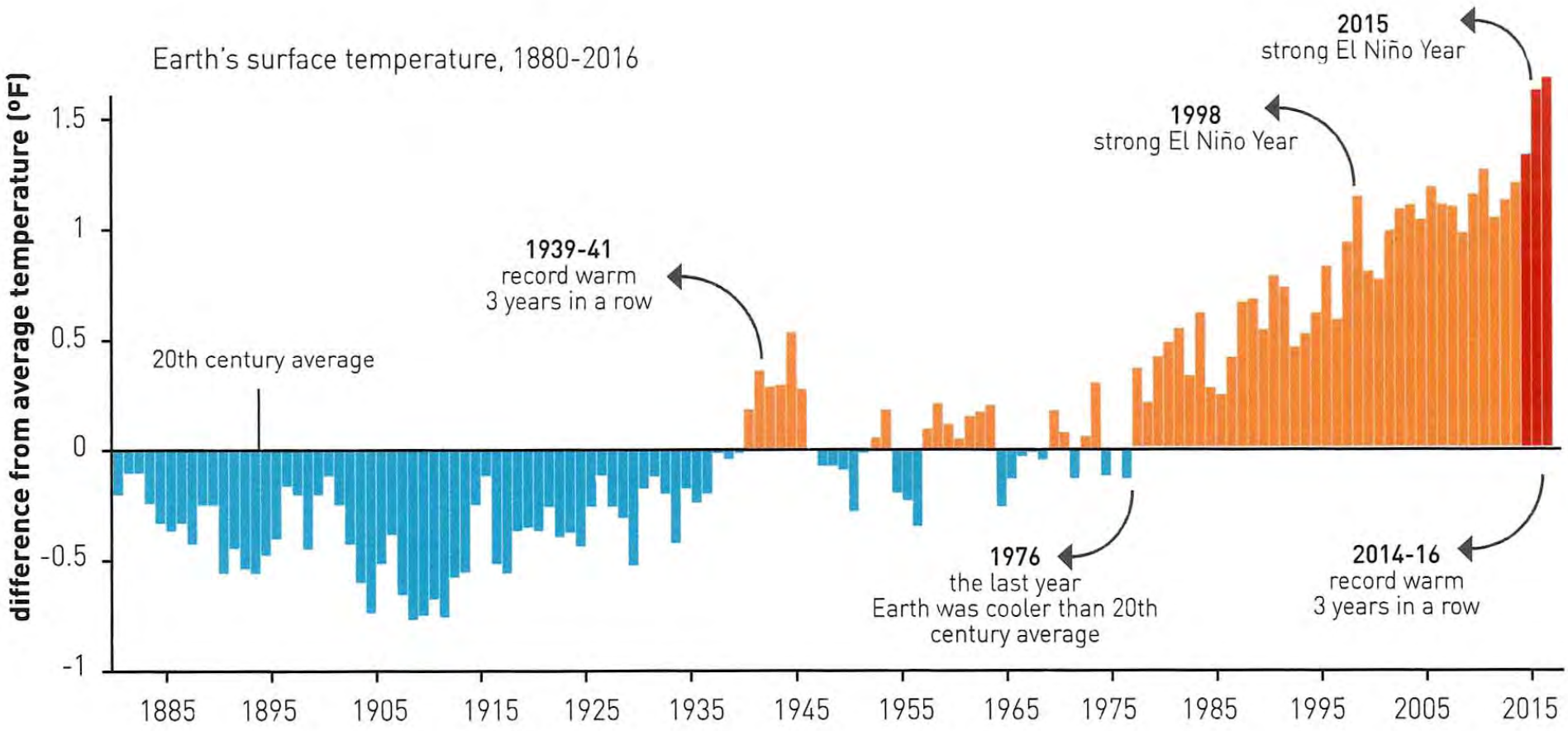
UPV-EHU

EARTH'S GREAT SERVICE TO HUMANKIND



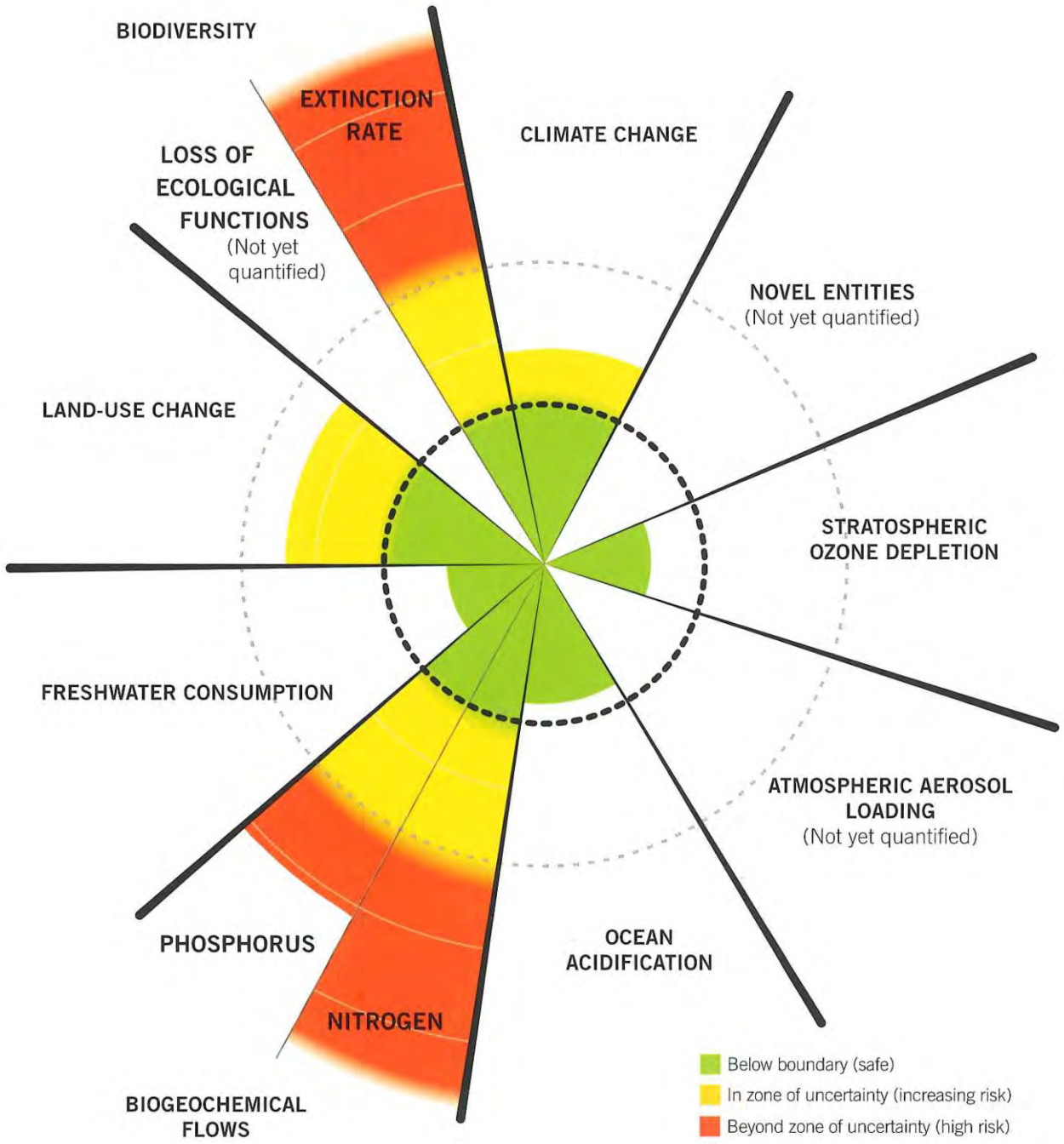
(Rockström, J. & Klum, M., 2015. Big World, Small Planet, 207 p)

UPV-EHU



(NOAA: climate.org)

UPV-EHU



(Rockström, J. & Klum, M., 2015. Big World, Small Planet, 207 p)

UPV-EHU

GLOBAL CHANGE NEWSLETTER

No. 41 May 2000

The International Geosphere–Biosphere Programme (IGBP): A Study of Global Change of the International Council for Science (ICSU)

The "Anthropocene"

by Paul J. Crutzen and Eugene F. Stoermer

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.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" (2). Stoppani in 1873 rated mankind's activities as a "new telluric force which in power and universality may be compared to the greater forces of earth" [quoted from Clark (3)]. Stoppani already spoke of the anthropozoic 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 (4) in 1926 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 "noösphere", 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 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 exhausting the fossil fuels that were generated over several hundred million years. The release of SO_2, 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-sulfide from the oceans (7); from Vitousek 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 in the atmosphere: CO_2 by more than 30% and CH_4 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). 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 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 Loutre (14), because of the anthropogenic emissions of CO_2, 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 CO_2 and CH_4 (7). Such a starting date also coincides with James Watt´s invention of the steam

UPV-EHU

Web of Science InCites Journal Citation Reports Essential Science Indicators EndNote Publons Sign In Help English

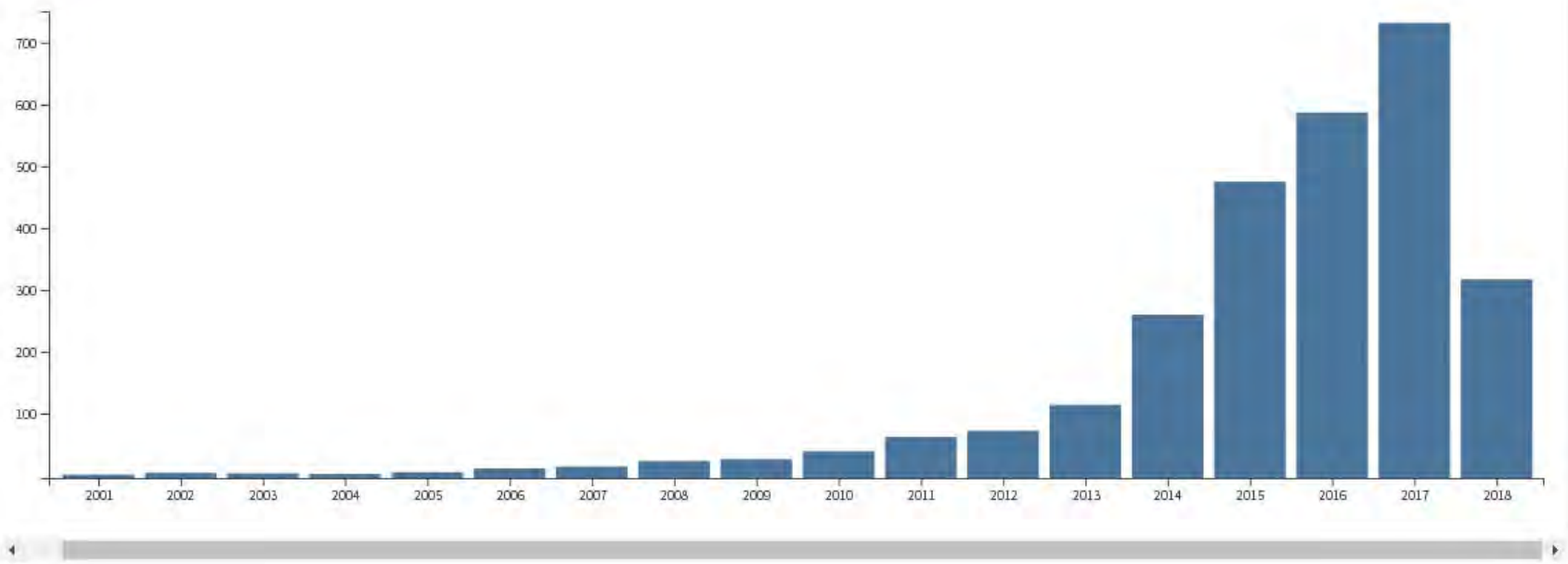
Web of Science

Clarivate Analytics

Search Search Results My Tools Searches and alerts Search History Marked List

Total Publications

2.747



Sum of Times Cited per Year

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

UPV-EHU

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. BUSHNELL, *Sermon on the Power of an Endless Life.*

NEW YORK:
CHARLES SCRIBNER, 124 GRAND STREET.
1864.

CORSO

DI

GEOLOGIA

DEL PROFESSORE

ANTONIO STOPPANI.

VOLUME II.

GEOLOGIA STRATIGRAFICA.

MILANO,
G. BERNARDONI E G. BRIGOLA, EDITORI.
—
1873.

THE NEXT GOLDEN STATE: A 16-PAGE SPECIAL REPORT ON AUSTRALIA

The Economist

Obama, Bibi and peace

Huntsman blows his horn

A soft landing for China

The costly war on cancer

How the brain drain reduces poverty

MAY 28TH–JUNE 3RD 2011 Economist.com

Welcome to the Anthropocene

Geology's new age

US$6.99 • C$7.99

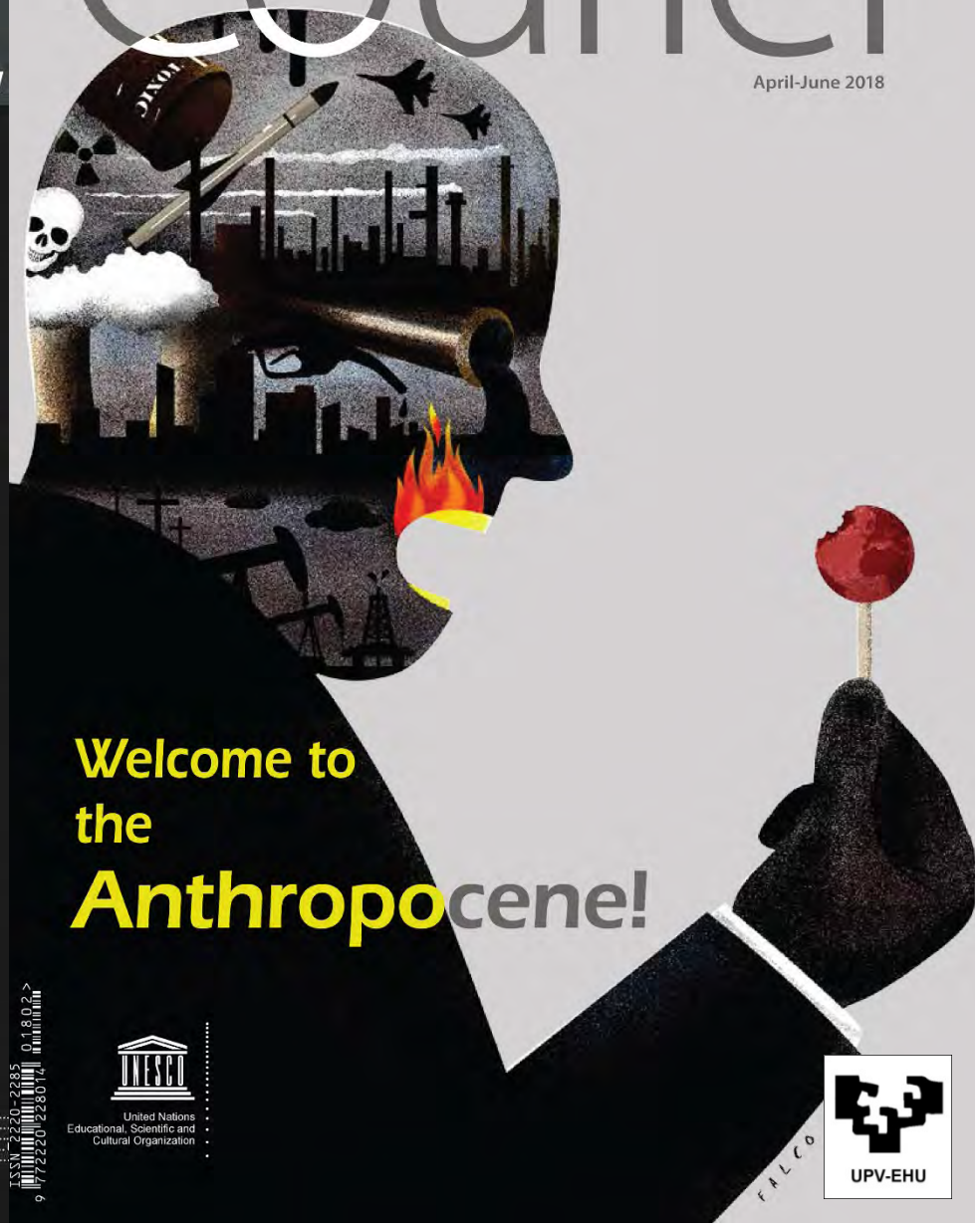
23

0 71658 02674 2

Argentina	$7.00	Canada	C$7.99	Jamaica	J$610	Trinidad & Tobago	
Bahamas	$9.95	Chile	Ch$5,000	Mexico	Mex$70	Turks & Caicos	
Barbados	Bds$16.50	Colombia	Col$22,000	Peru	S/.39.00	UK	
Bermuda	BD$7.00	Costa Rica	₡6,900	Spain	€5.80	USA	
Brazil	R$24.90	Guyana	GYD 1,650	St.Maarten	$9.25	Venezuela	

THE UNESCO Courier

April-June 2018



Welcome to the Anthropocene!

ISSN 2220-2285

United Nations Educational, Scientific and Cultural Organization

UPV-EHU

Anthropocene Working Group (since 2009)

UPV-EHU

GROUNDWORK

Furthering the Influence of Earth Science

Is the Anthropocene an issue of stratigraphy or pop culture?

***Whitney J. Autin**, Dept. of Earth Sciences, SUNY College at Brockport, Brockport, New York 14420, USA, dirtguy@esc.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 the broader scientific community solidify the idea of humanity as an Earth-system driver. Before the scientific community ventures 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 Stoermer (2000) 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 no
symbiotic relationship with nature. Humanity no
natural processes, such as biogeochemical cycles,
atmosphere transfers, and flux of surficial sedim
al., 2011). Accelerated mass transfer of sediments
Wilkinson, 2005) has particular interest because e
sedim

RELEV
The
time te
anthro
stratigr
bound
concep
best a b
been fo
stratigr
curren
lasting
Forn
a codif
amend
for stra
definit
of Eart
rock co
geophy
measu
Beca
fully de
recogn
epoch,
stratigr
appear
time. A
proble
identif
centur
bound
bound
precisi
across
specifi
Forn
implies
if equiv
Holoce
prefera
Anthro
correla
task th

GSA Today, v. 22, no. 7, doi: 10.1130/G153GW.1.

Rend. Fis. Acc. Lincei (2014) 25:381–392
DOI 10.1007/s12210-014-0317-x

THE TWO CULTURES

Anthropocene: another academic invention?

Guido Visconti

st 2014
ink.com

ntroduction

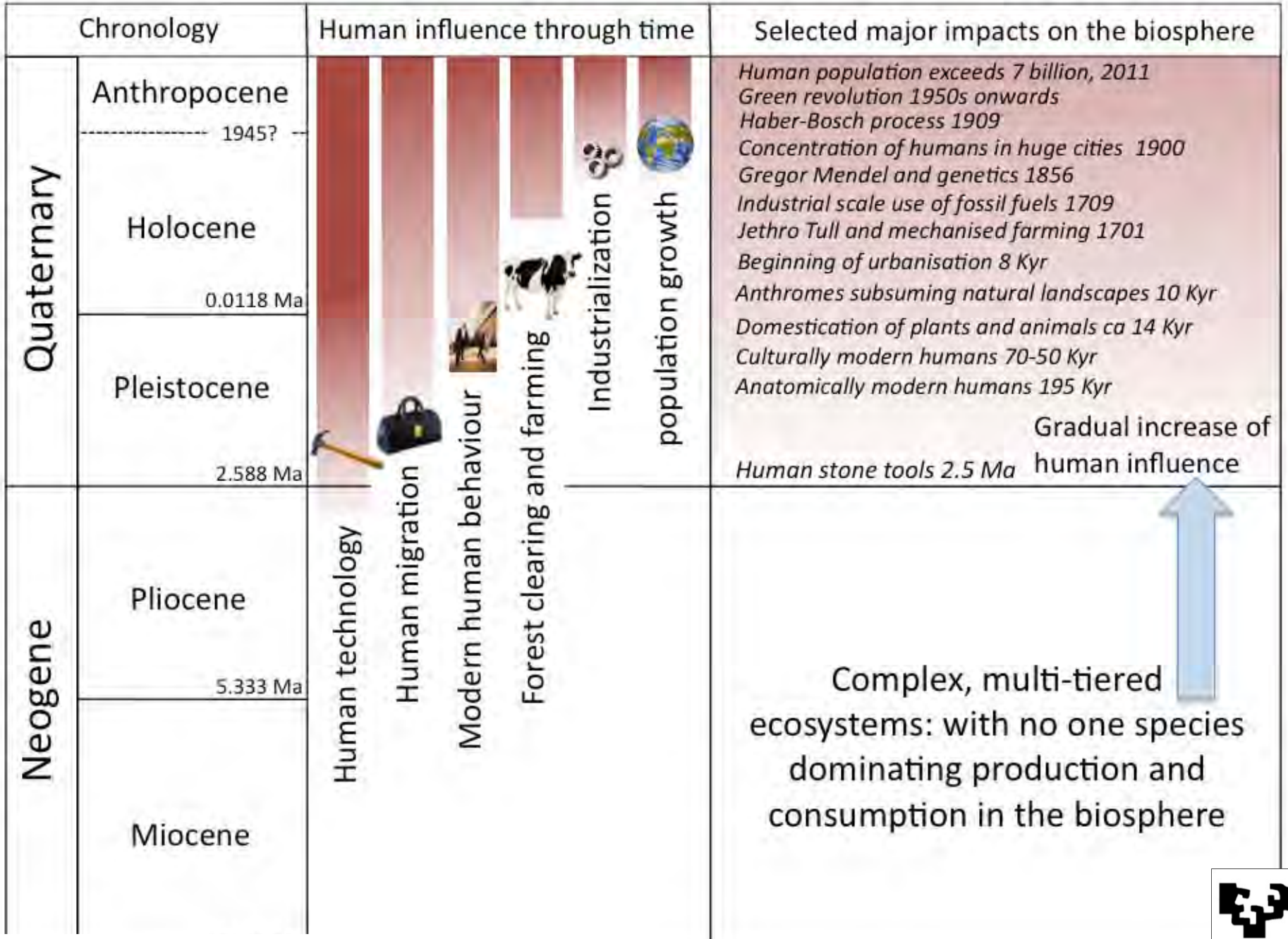
idea of Anthropocene was introduced by Crutzen and
ermer (2000) (apparently Stoermer has used the term
e early 1980s) in a paper in the *Global Change*
sletter of the IGBP in May 2000. The idea was
ewhat refined as a concept in a one-page article in
ure in 2002 (Crutzen 2002). Since then, the Anthro-
ene has been the subject of papers, meetings,[1] and
arch and discussion at the scientific, political, and
osophical levels. The Anthropocene should define a
geologic epoch of the Quaternary Period and appar-
y should not change at all the substance of things, even
the political and economic perspectives of the present
ch.

The initial response to the idea came mainly from
logy. Recently Autin and Holbrook (2012) observed
the main problem was that the proposed Anthropocene
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 stratigraphy issue seems to be the most important as
ssed recently by Finney (2013) and Cohen et al. (2013).
ey raises a number of issues that must be addressed
de the stratigraphic one. They refer to the Anthropo-
e being a unit of Earth history or human history that is
e like a projection into the future. This point stresses
fact that since the last millennium human observations
re and more complete and refined) will be used to study

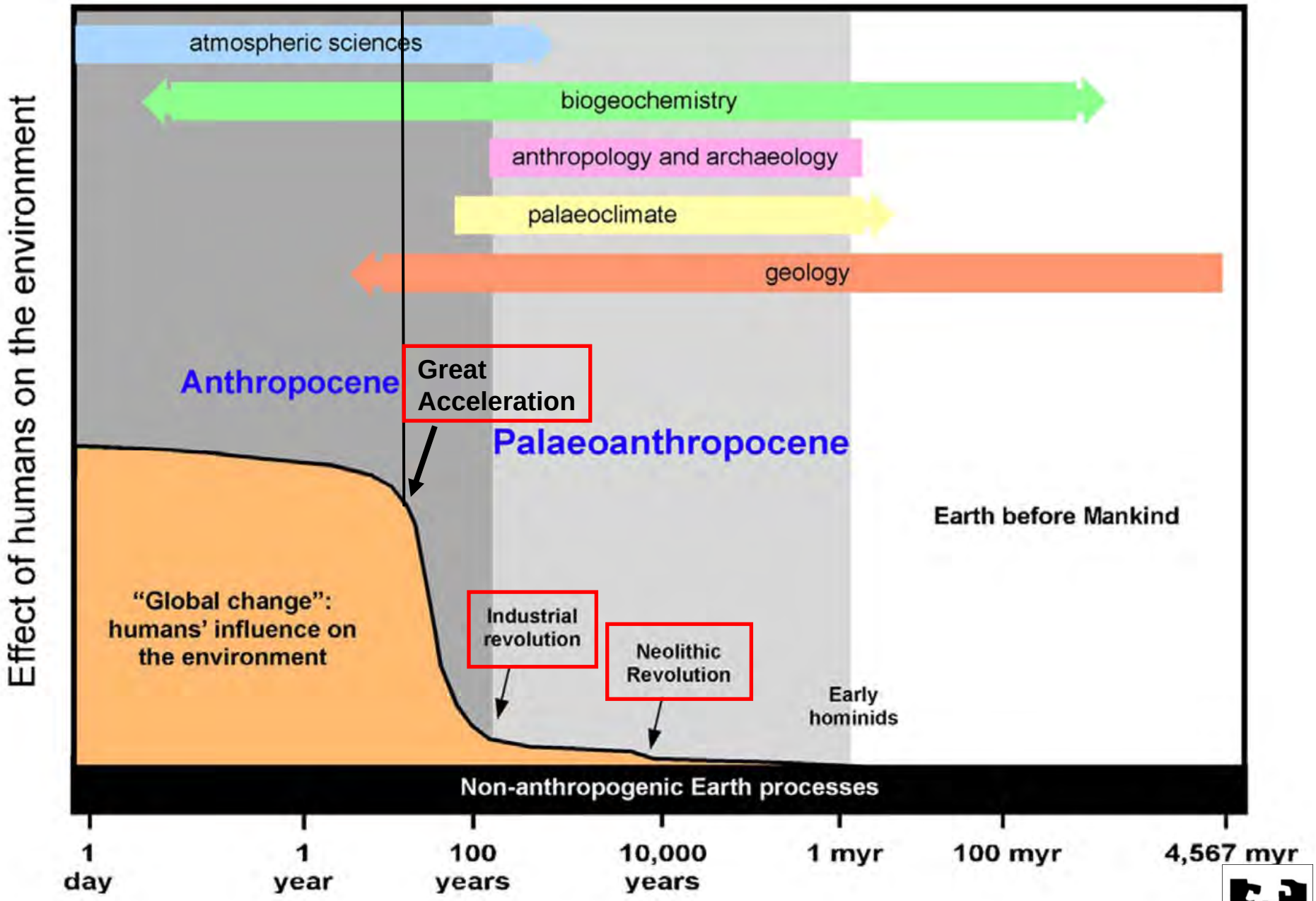
e the March 2014 issue of Rendiconti Lincei with the papers
ented at the conference: *Anthropocene: natural and man-made*
ations of the Earth's fragile equilibrium held
Lincei, Rome, November 26-27, 2012.

UPV-EHU



(Williams, M. et al., 2016. Earth's Future, 4, 1-20)

UPV-EHU

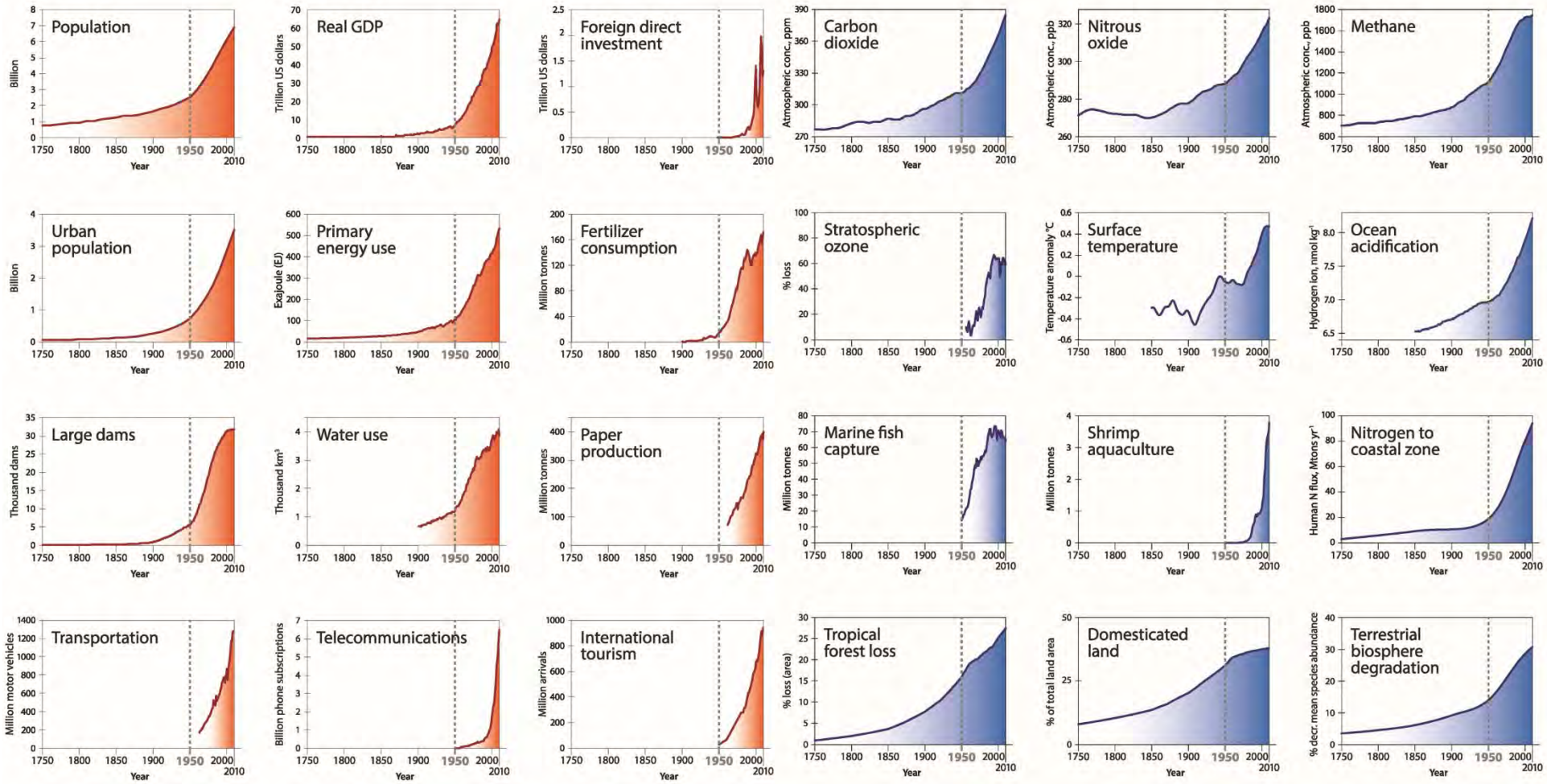


(Foley, S.F. et al., 2013. Anthropocene, 3, 83-88)

UPV-EHU

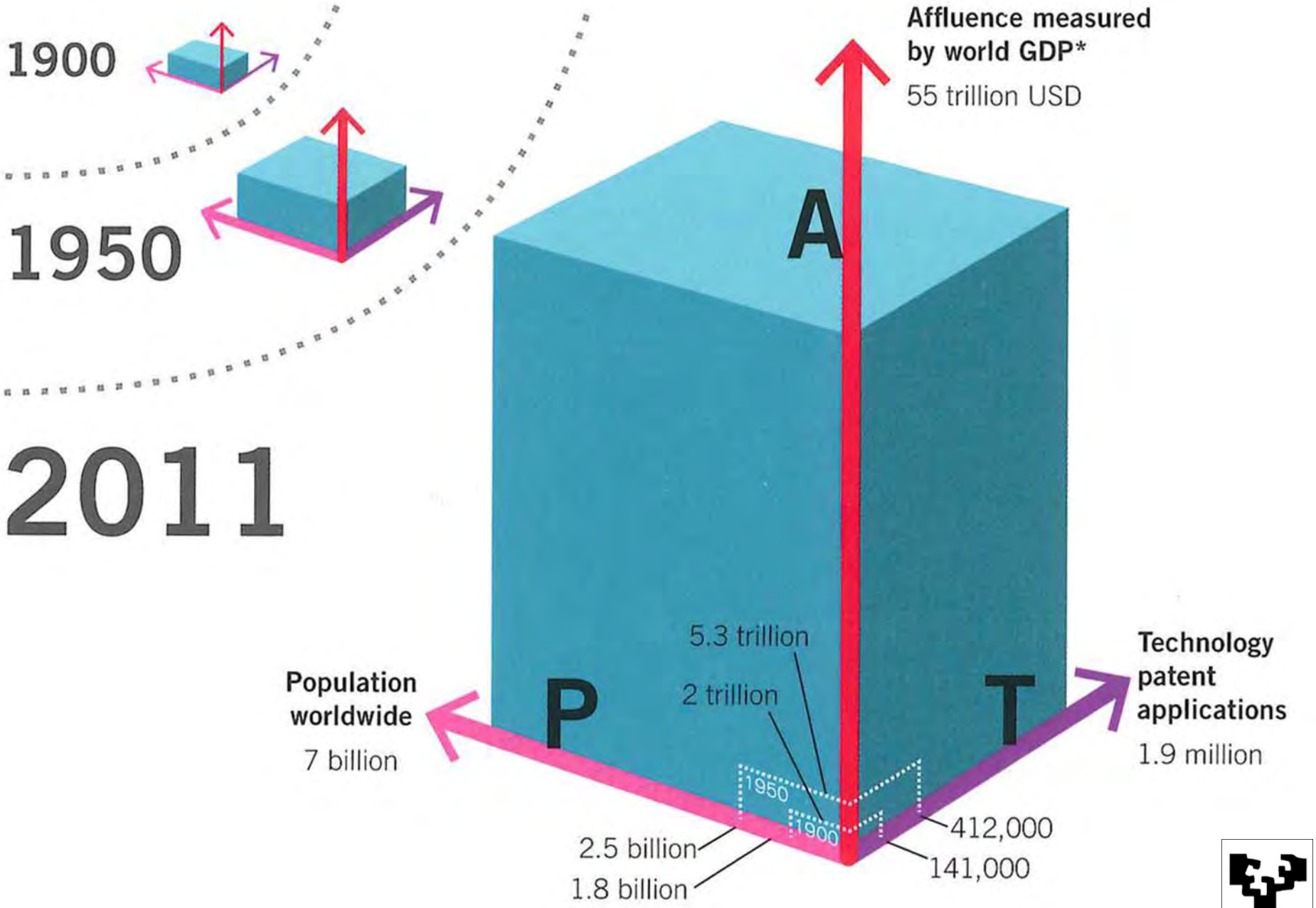
Socio-economic trends

Earth system trends

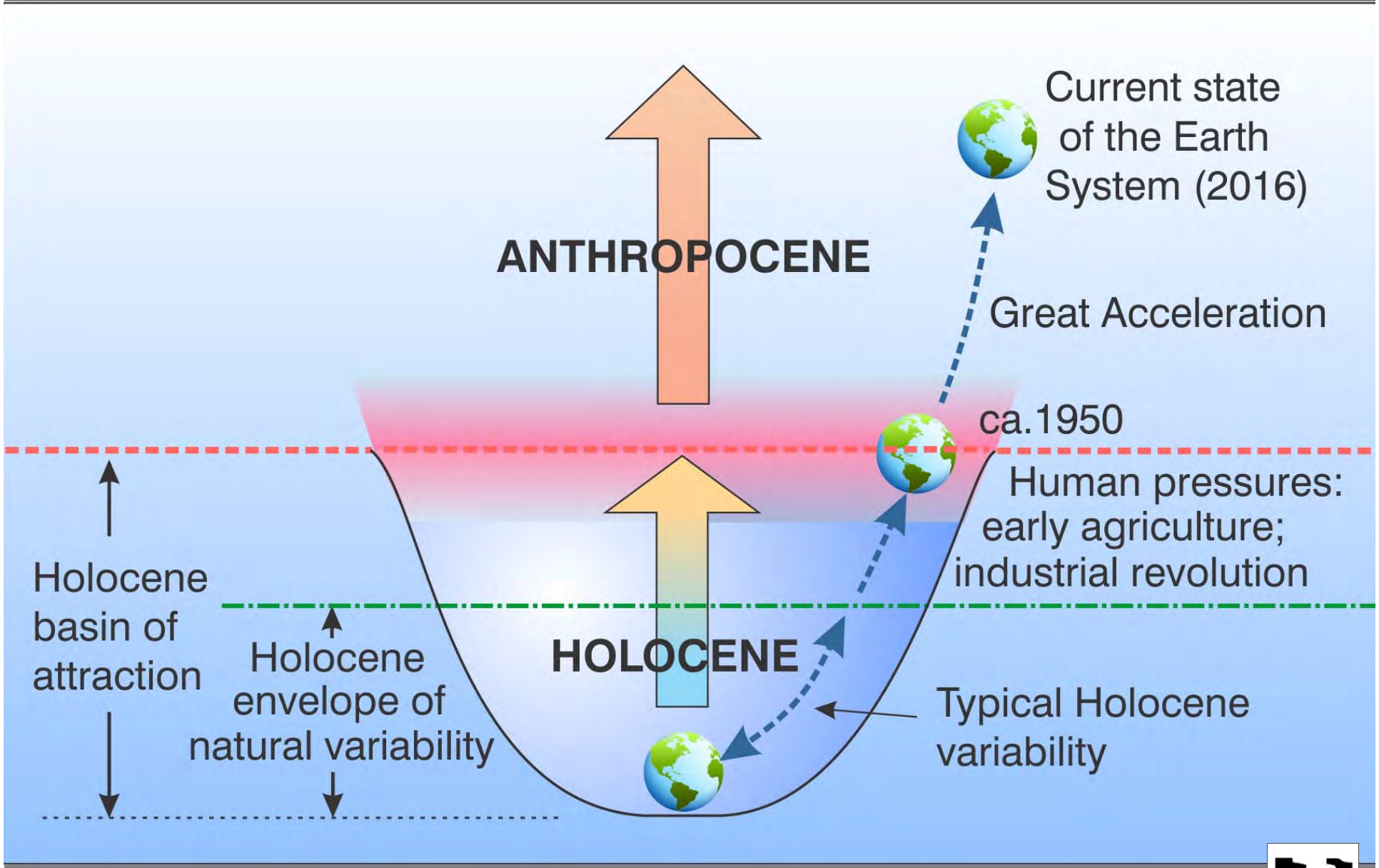


(Steffen, W. et al., 2015. The Anthropocene Review, 2, 81-98)

UPV-EHU

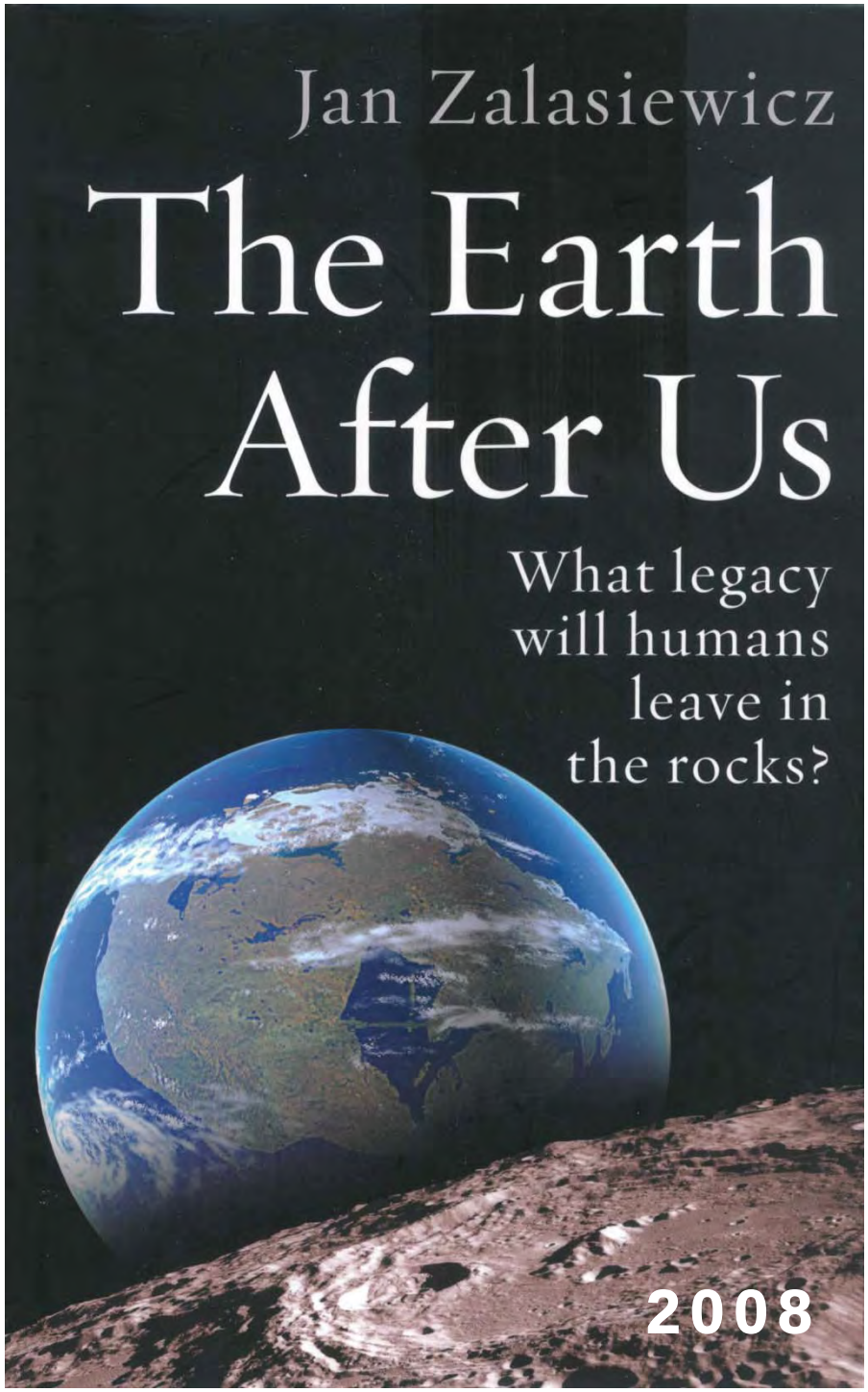


(Steffen, W. et al., 2011. Ambio, 40, 739-761)



(Steffen, W. et al., 2016. Earth's Future, 4, 324-345)

UPV-EHU



Research article

THE ANTHROPOCENE REVIEW

The Anthropocene Review
2014, Vol. 1(1) 34–43

DOI: 10.1177/2053019613514953
anr.sagepub.com
SAGE

The technofossil record of humans

Jan Zalasiewicz,[1] Mark Williams,[1] Colin N Waters,[2] Anthony D Barnosky[3,4,5] 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

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

Corresponding author:
Jan Zalasiewicz, Department of Geology, University Leicester, University Road, Leicester LE1 7RH, UK.
Email: jaz1@le.ac.uk

UPV-EHU

Quaternary International 383 (2015) 196–203

Contents lists available at ScienceDirect

Quaternary International

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

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

Jan Zalasiewicz [a], Colin N. Waters [b, *], Mark Williams [a], Anthony D. Barnosky [c], Alejandro Cearreta [d], Paul Crutzen [e], Erle Ellis [f], Michael A. Ellis [b], Ian J. Fairchild [g], Jacques Grinevald [h], Peter K. Haff [i], Irka Hajdas [j], Reinhold Leinfelder [k], John McNeill [l], Eric O. Odada [m], Clément Poirier [n], Daniel Richter [o], Will Steffen [p], Colin Summerhayes [q], James P.M. Syvitski [r], Davor Vidas [s], Michael Wagreich [t], Scott L. Wing [u], Alexander P. Wolfe [v], An Zhisheng [w], Naomi Oreskes [x]

[a] Department of Geology, University of Leicester, University Road, Leicester LE1 7RH, UK
[b] British Geological Survey, Keyworth, Nottingham NG12 5GG, UK
[c] Dept. of Integrative Biology, Museum of Paleontology, Museum of Vertebrate Zoology, University of California, Berkeley, CA 94720, USA
[d] Departamento de Estratigrafía y Paleontología, Facultad de Ciencia y Tecnología, Universidad del País Vasco UPV/EHU, Apartado 644, 48080 Bilbao, Spain
[e] Max-Planck-Institute for Chemistry, Department of Atmospheric Chemistry, PO Box 3060, D-55020 Mainz, Germany
[f] Department of Geography and Environmental Systems, University of Maryland Baltimore County, Baltimore, MD 21250, USA
[g] School of Geography, Earth and Environmental Sciences, University of Birmingham, B15 2TT, UK
[h] IHEID, Chemin Eugène Rigot 2, 1211 Genève 11, Switzerland
[i] Division of Earth and Ocean Sciences, Nicholas School of the Environment, Duke University, Box 90233, Durham, NC 27516, USA
[j] ETH Zurich, Laboratory of Ion Beam Physics, HPK H27, Otto-Stern-Weg 5, CH-8093 Zürich, Switzerland
[k] Department of Geological Sciences, Freie Universität Berlin, Malteserstr. 74-100/D, 12249 Berlin, Germany
[l] Georgetown University, Washington, DC, USA
[m] Department of Geology, University of Nairobi, Kenya
[n] Morphodynamique Continentale et Côtière, Université de Caen Basse Normandie, CNRS, 24 rue des Tilleuls, F-14000 Caen, France
[o] Nicholas School of the Environment, Duke University, Durham, NC, USA
[p] The Australian National University, Canberra, ACT 0200, Australia
[q] Scott Polar Research Institute, Cambridge University, Lensfield Road, Cambridge CB2 1ER, UK
[r] University of Colorado-Boulder Campus, Box 545, Boulder, CO 80309-0545, USA
[s] Marine Affairs and Law of the Sea Programme, The Fridtjof Nansen Institute, Norway
[t] Department of Geodynamics and Sedimentology, University of Vienna, A-1090 Vienna, Austria
[u] Dept. of Paleobiology, NHB121, PO Box 37012, Museum of Natural History, Smithsonian Institution, Washington, DC, USA
[v] Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB T6G 2E3, Canada
[w] The Institute of the Earth Environment, Chinese Academy of Sciences, 10 Fenghui South Road, Xi'an High-Tech Zone, Xi'an 710075, China
[x] Department of the History of Science, Harvard University, Cambridge, MA 02138, USA

ARTICLE INFO

Article history:
Available online 12 January 2015

Keywords:
Anthropocene
Stratigraphy
GSSP
GSSA

ABSTRACT

We evaluate the boundary of the Anthropocene geological time interval as an epoch, since it is useful to have a consistent temporal definition for this increasingly used unit, whether the presently informal term is eventually formalized or not. Of the three main levels suggested – an 'early Anthropocene' level some thousands of years ago; the beginning of the Industrial Revolution at ~1800 CE (Common Era); and the 'Great Acceleration' of the mid-twentieth century – current evidence suggests that the last of these has the most pronounced and globally synchronous signal. A boundary at this time need not have a Global Boundary Stratotype Section and Point (GSSP or 'golden spike') but can be defined by a Global Standard Stratigraphic Age (GSSA), i.e. a point in time of the human calendar. We propose an appropriate boundary level here to be the time of the world's first nuclear bomb explosion, on July 16th 1945 at Alamogordo, New Mexico; additional bombs were detonated at the average rate of one every 9.6 days until 1988 with attendant worldwide fallout easily identifiable in the chemostratigraphic record. Hence, Anthropocene deposits would be those that may include the globally distributed primary artificial

* Corresponding author.
E-mail address: ja21@leicester.ac.uk (J. Zalasiewicz).

http://dx.doi.org/10.1016/j.quaint.2014.11.045
1040-6182/

IT IS 3 MINUTES TO MIDNIGHT

Bulletin of the Atomic Scientists | 70 Years Speaking Knowledge to Power

Feature

Bulletin of the Atomic Scientists
2015, Vol. 71(3) 46–57

DOI: 10.1177/0096340215581357
http://thebulletin.sagepub.com
SAGE

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 Cearreta, Jacques Grinevald, Catherine Jeandel, J. R. McNeill, Colin Summerhayes, and Anthony Barnosky

Abstract

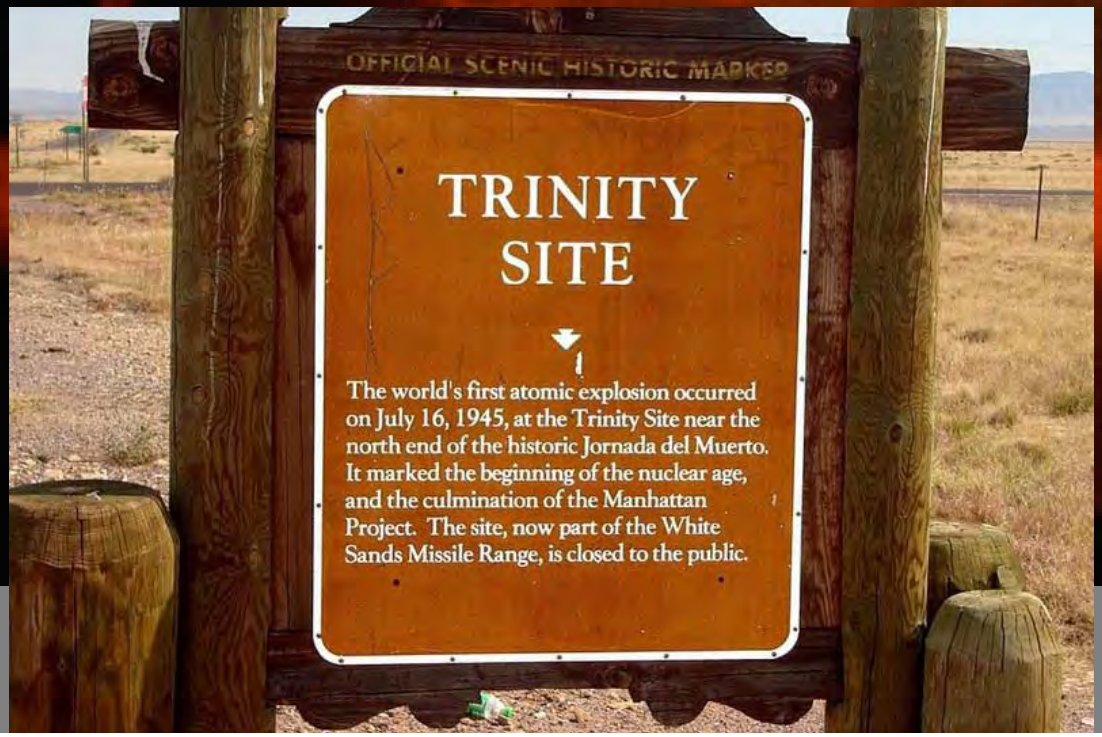
Many scientists are making the case that humanity is living in a new geological epoch, the Anthropocene, but there is no agreement yet as to when this epoch began. The start might be defined by a historical event, such as the beginning of the fossil-fueled Industrial Revolution or the first nuclear explosion 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

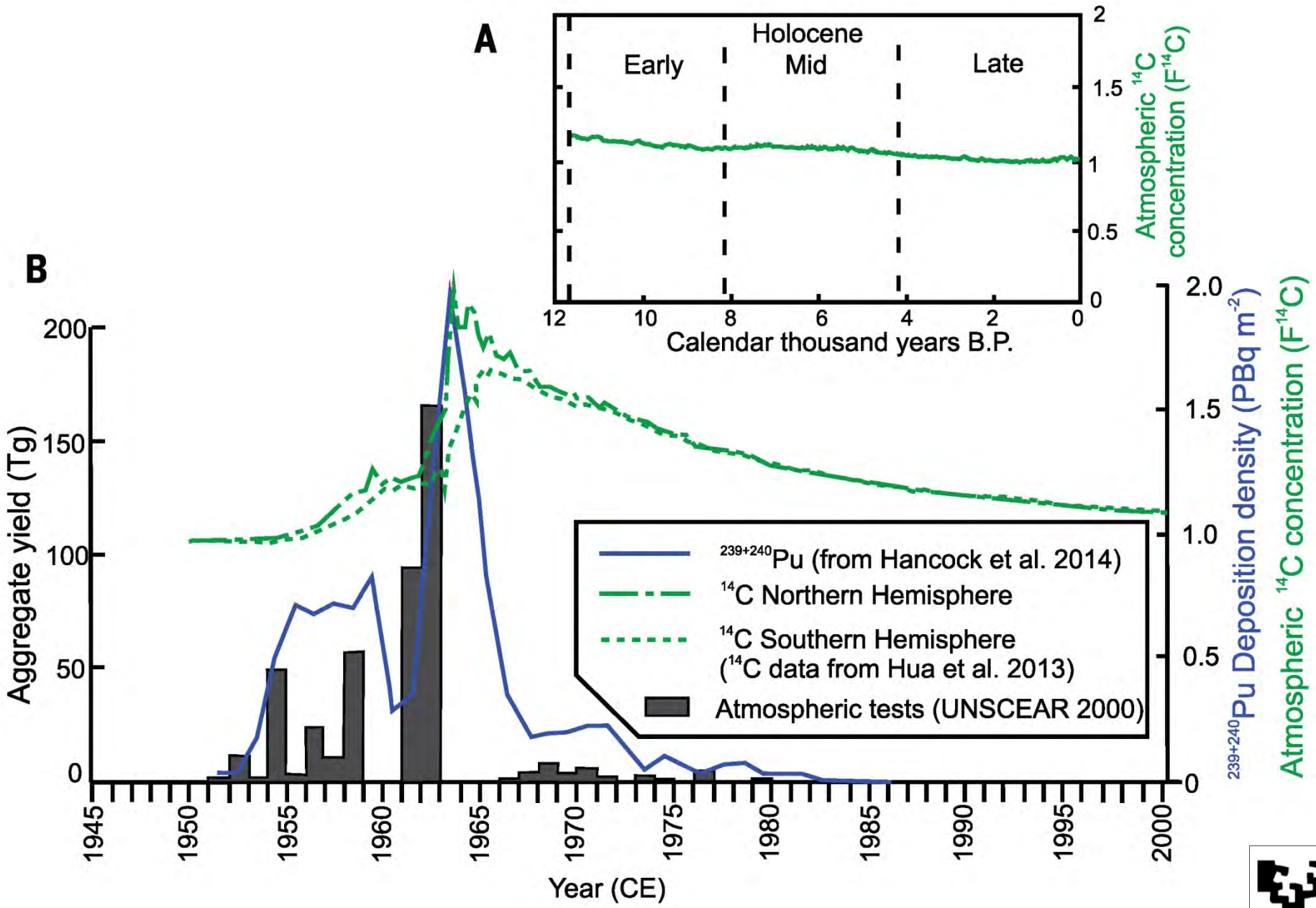
Anthropocene, golden spike, nuclear weapons fallout, radioactive isotope, radiogenic signature, Trinity test

Seventy years ago—at 5:30 a.m. on July 16, 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 7.5 miles high. J. Robert Oppenheimer lat[illegible] that he and other Manhattan

UPV-EHU

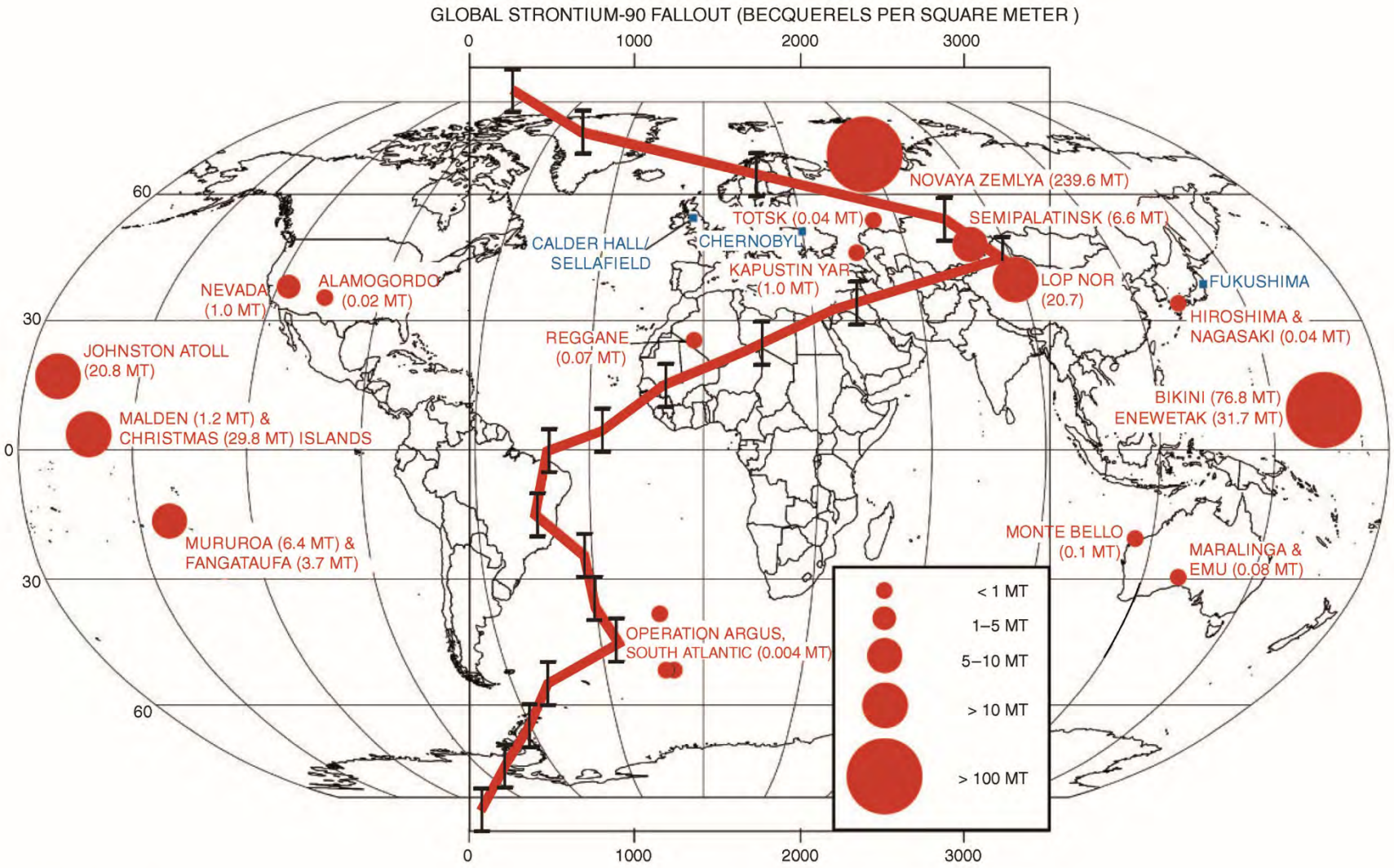

OFFICIAL SCENIC HISTORIC MARKER
TRINITY SITE
The world's first atomic explosion occurred on July 16, 1945, at the Trinity Site near the north end of the historic Jornada del Muerto. It marked the beginning of the nuclear age, and the culmination of the Manhattan Project. The site, now part of the White Sands Missile Range, is closed to the public.

UPV-EHU



(Waters, C.N. et al., 2016. Science, 351 (6269), aad2622-1/10)

UPV-EHU



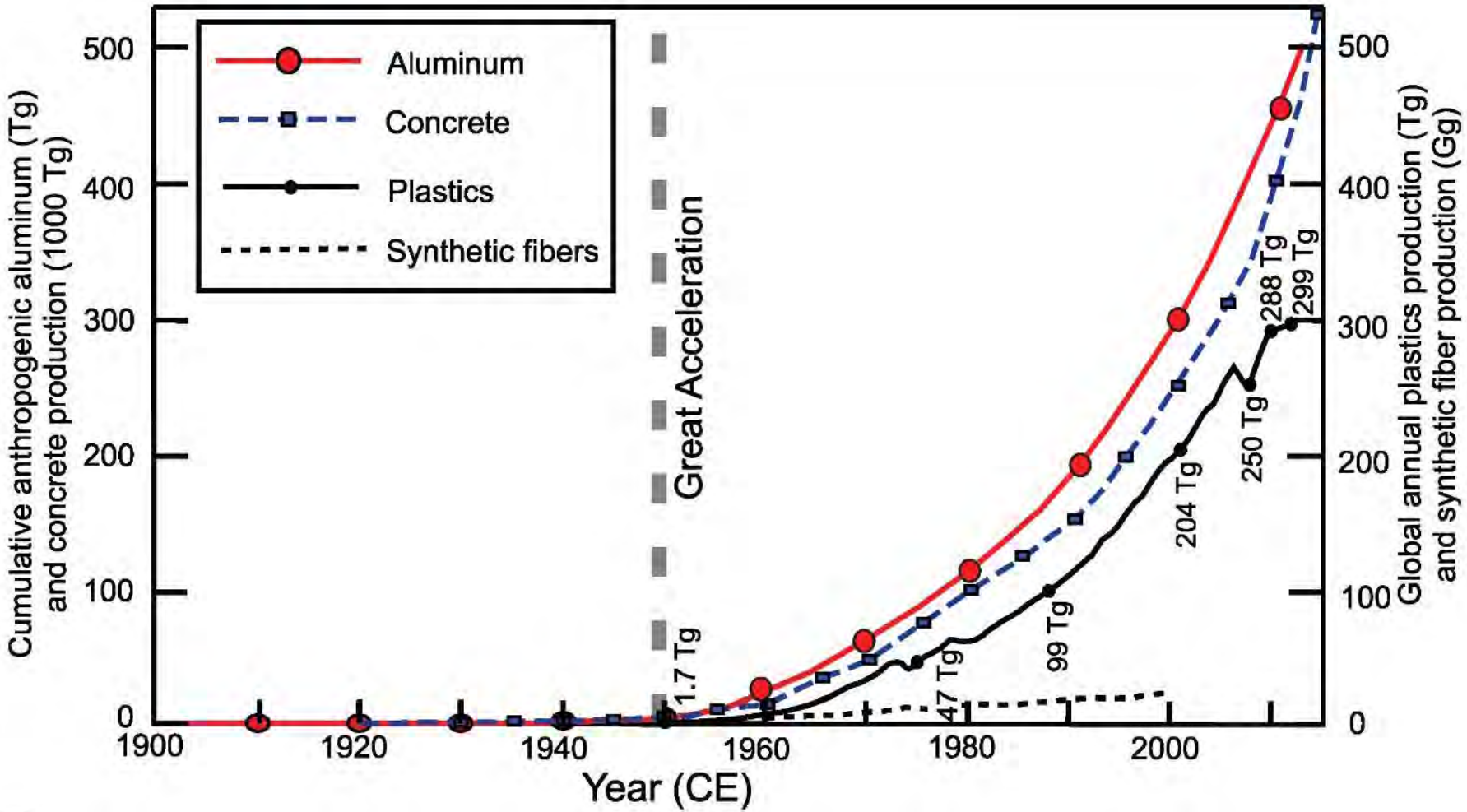
Source: UNSCEAR (2000)

(Waters, C.N. et al., 2015. Bulletin of the Atomic Scientists, 71, 46-57)

UPV-EHU

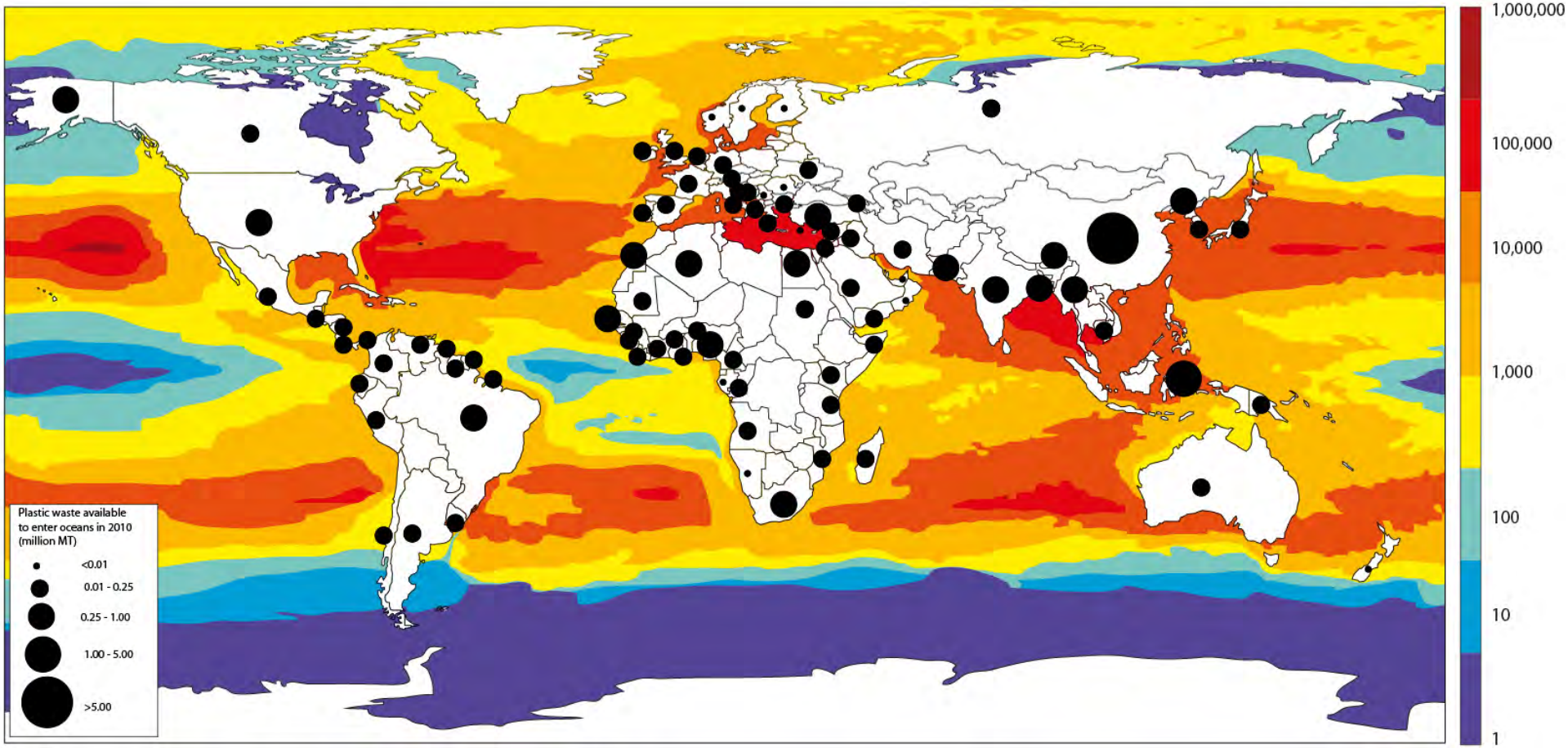
(Waters, C.N. et al., 2014. Geological Society of London Special Publications, 395, 1-21)

UPV-EHU



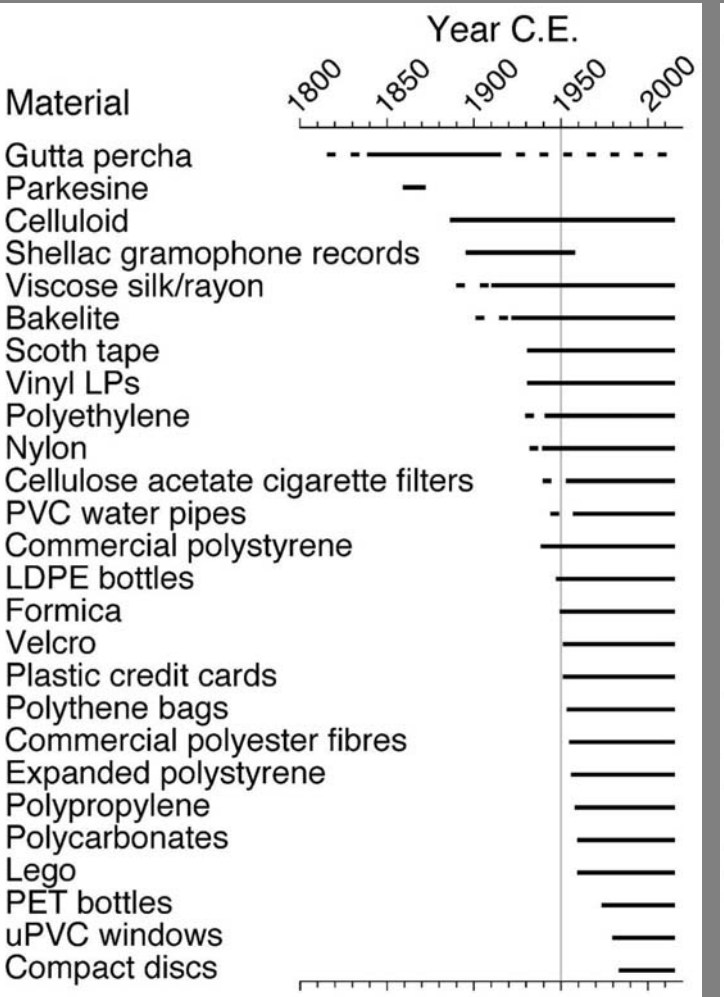
(Waters, C.N. et al., 2016. Science, 351 (6269), aad2622-1/10)

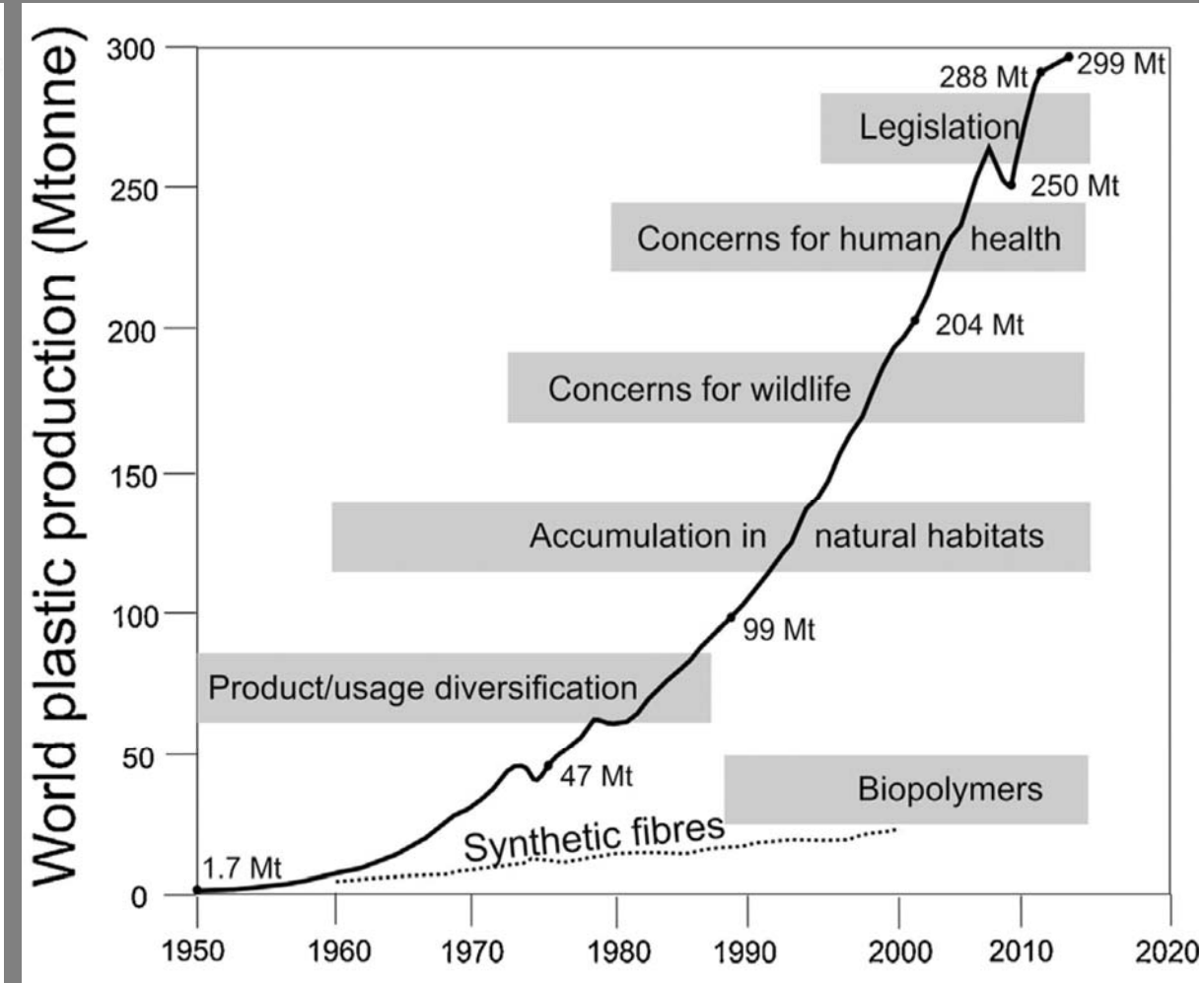
UPV-EHU



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

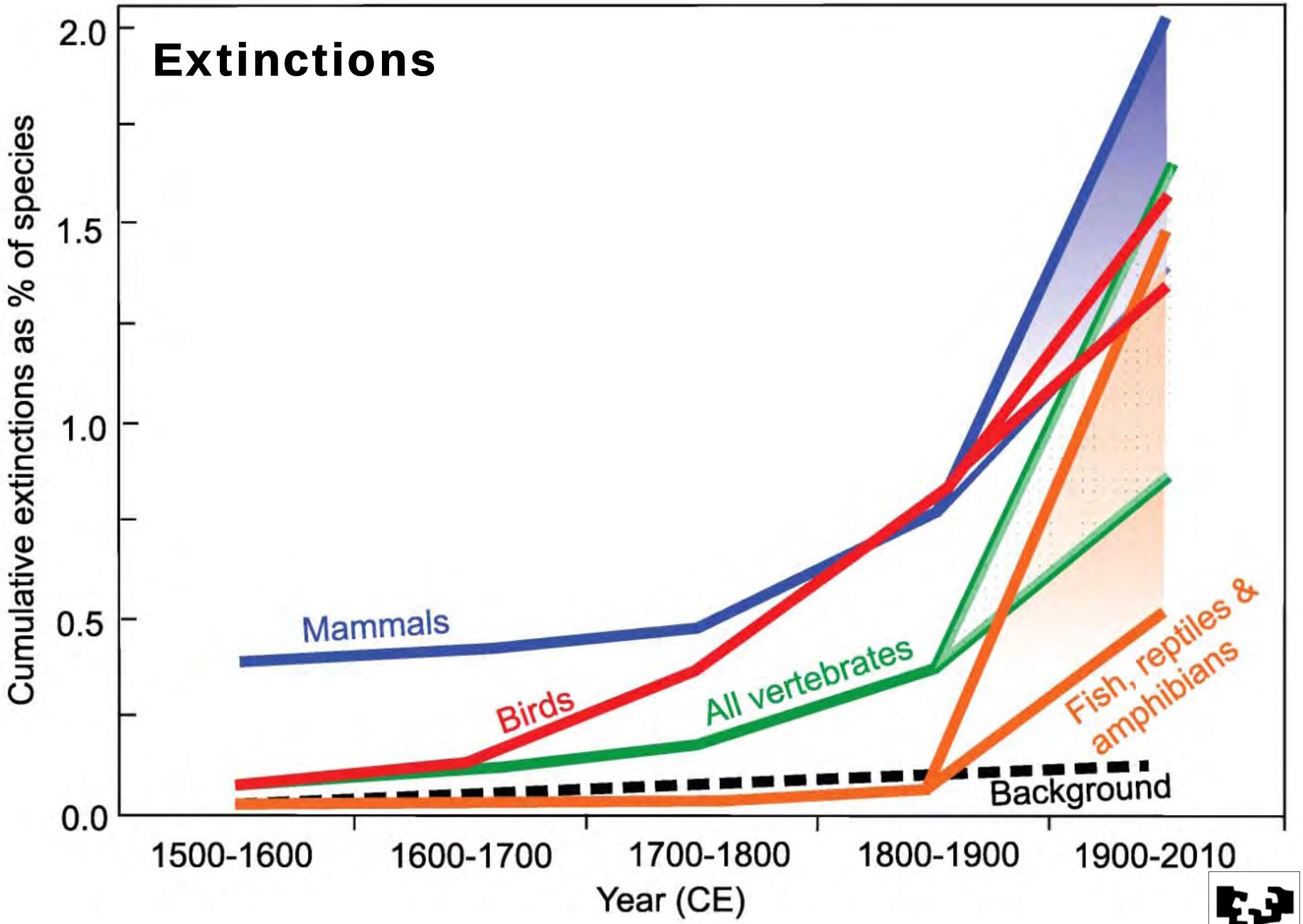
UPV-EHU





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

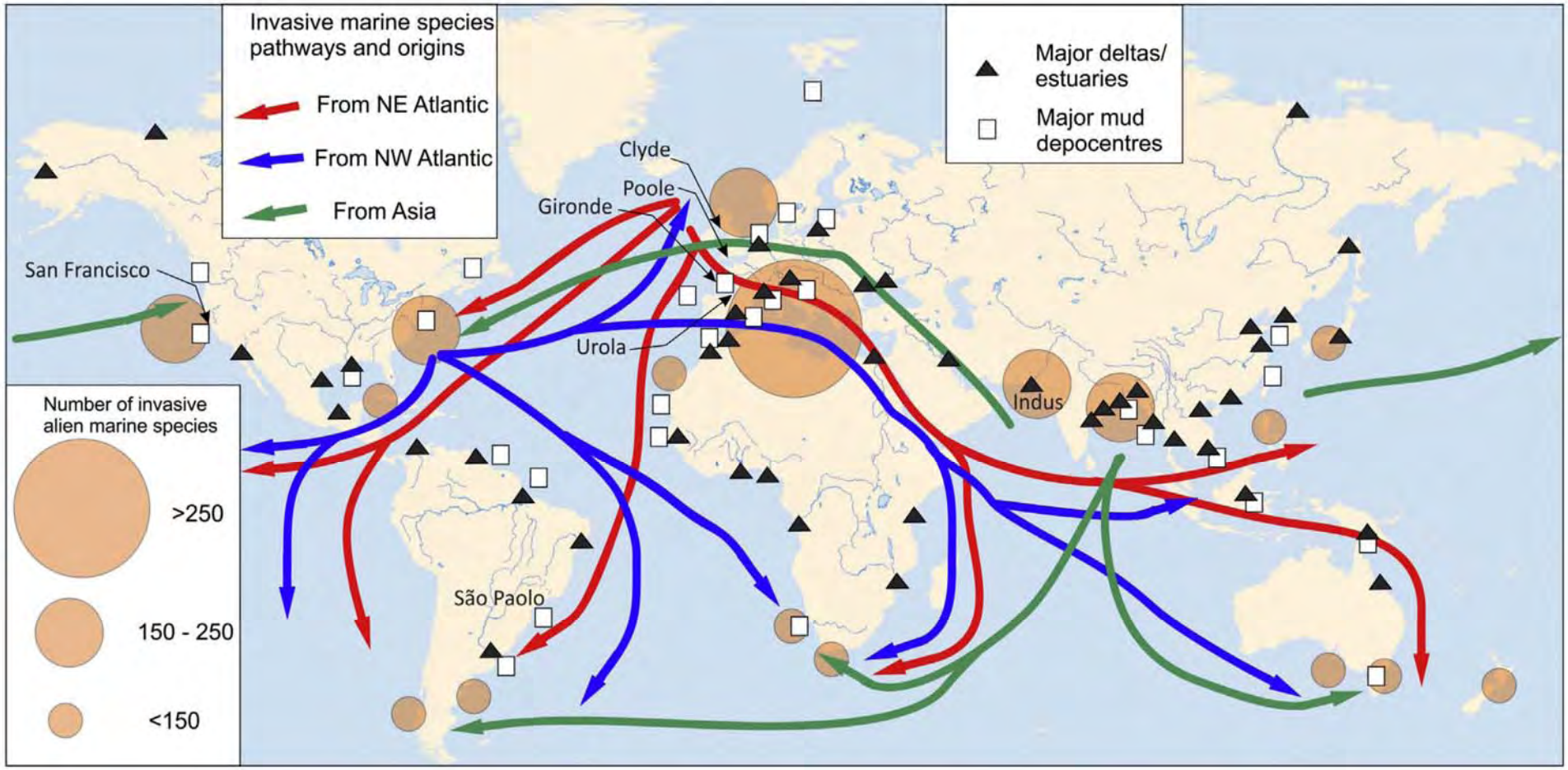
UPV-EHU



(Waters, C.N. et al., 2016. Science, 351 (6269), aad2622-1/10)

UPV-EHU

Neobiota



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

UPV-EHU

INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

IUGS

www.stratigraphy.org — **International Commission on Stratigraphy** — **v 2016/04**

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
						present
Phanerozoic	Cenozoic	Quaternary	Holocene			0.0117
			Pleistocene	*Upper*		0.126
				Middle		0.781
				Calabrian		1.80
				Gelasian		2.58
		Neogene	Pliocene	Piacenzian		3.600
				Zanclean		5.333
			Miocene	Messinian		7.246
				Tortonian		11.63
				Serravallian		13.82
				Langhian		15.97
				Burdigalian		20.44
				Aquitanian		23.03
		Paleogene	Oligocene	Chattian		28.1
				Rupelian		33.9
			Eocene	Priabonian		37.8
				Bartonian		41.2
				Lutetian		47.8
				Ypresian		56.0
			Paleocene	Thanetian		59.2
				Selandian		61.6
				Danian		66.0
Mesozoic		Cretaceous	Upper	Maastrichtian		72.1 ±0.2
				Campanian		83.6 ±0.2
				Santonian		86.3 ±0.5
				Coniacian		89.8 ±0.3
				Turonian		93.9
				Cenomanian		100.5
			Lower	Albian		~ 113.0
				Aptian		~ 125.0
				Barremian		~ 129.4
				Hauterivian		~ 132.9
				Valanginian		~ 139.8
				Berriasian		~ 145.0

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
Phanerozoic	Mesozoic	Jurassic	Upper	Tithonian		~ 145.0
				Kimmeridgian		152.1 ±0.9
				Oxfordian		157.3 ±1.0
			Middle	Callovian		163.5 ±1.0
				Bathonian		166.1 ±1.2
				Bajocian		168.3 ±1.3
				Aalenian		170.3 ±1.4
			Lower	Toarcian		174.1 ±1.0
				Pliensbachian		182.7 ±0.7
				Sinemurian		190.8 ±1.0
				Hettangian		199.3 ±0.3
		Triassic	Upper	Rhaetian		201.3 ±0.2
				Norian		~ 208.5
				Carnian		~ 227
			Middle	Ladinian		~ 237
				Anisian		~ 242
			Lower	Olenekian		247.2
				Induan		251.2
Phanerozoic	Paleozoic	Permian	Lopingian	Changhsingian		252.17 ±0.06
				Wuchiapingian		254.14 ±0.07
			Guadalupian	Capitanian		259.8 ±0.4
				Wordian		265.1 ±0.4
				Roadian		268.8 ±0.5
			Cisuralian	Kungurian		272.3 ±0.5
				Artinskian		283.5 ±0.6
				Sakmarian		290.1 ±0.26
				Asselian		295.0 ±0.18
		Carboniferous – Pennsylvanian	Upper	Gzhelian		298.9 ±0.15
				Kasimovian		303.7 ±0.1
			Middle	Moscovian		307.0 ±0.1
			Lower	Bashkirian		315.2 ±0.2
		Carboniferous – Mississippian	Upper	Serpukhovian		323.2 ±0.4
			Middle	Visean		330.9 ±0.2
			Lower	Tournaisian		346.7 ±0.4
						358.9 ±0.4

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
Phanerozoic	Paleozoic	Devonian	Upper	Famennian		358.9 ± 0.4
				Frasnian		372.2 ±1.6
			Middle	Givetian		382.7 ±1.6
				Eifelian		387.7 ±0.8
			Lower	Emsian		393.3 ±1.2
				Pragian		407.6 ±2.6
				Lochkovian		410.8 ±2.8
		Silurian	Pridoli			419.2 ±3.2
			Ludlow	Ludfordian		423.0 ±2.3
				Gorstian		425.6 ±0.9
			Wenlock	Homerian		427.4 ±0.5
				Sheinwoodian		430.5 ±0.7
			Llandovery	Telychian		433.4 ±0.8
				Aeronian		438.5 ±1.1
				Rhuddanian		440.8 ±1.2
		Ordovician	Upper	Hirnantian		443.8 ±1.5
				Katian		445.2 ±1.4
				Sandbian		453.0 ±0.7
			Middle	Darriwilian		458.4 ±0.9
				Dapingian		467.3 ±1.1
			Lower	Floian		470.0 ±1.4
				Tremadocian		477.7 ±1.4
		Cambrian	Furongian	*Stage 10*		485.4 ±1.9
				Jiangshanian		~ 489.5
				Paibian		~ 494
			Series 3	Guzhangian		~ 497
				Drumian		~ 500.5
				Stage 5		~ 504.5
			Series 2	*Stage 4*		~ 509
				Stage 3		~ 514
			Terreneuvian	*Stage 2*		~ 521
				Fortunian		~ 529
						541.0 ±1.0

Eonothem / Eon	Erathem / Era	System / Period	GSSP GSSA	numerical age (Ma)
Precambrian	Proterozoic	Neo-proterozoic	Ediacaran	541.0 ±1.0
			Cryogenian	~ 635
			Tonian	~ 720
		Meso-proterozoic	Stenian	1000
			Ectasian	1200
			Calymmian	1400
		Paleo-proterozoic	Statherian	1600
			Orosirian	1800
			Rhyacian	2050
			Siderian	2300
	Archean	Neo-archean		2500
		Meso-archean		2800
		Paleo-archean		3200
		Eo-archean		3600
		Hadean		4000
				~ 4600

Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (GSSP) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA). Charts and detailed information on ratified GSSPs are available at the website http://www.stratigraphy.org. The URL to this chart is found below.

Numerical ages are subject to revision and do not define units in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (~) is provided.

Numerical ages for all systems except Lower Pleistocene, Permian, Triassic, Cretaceous and Precambrian are taken from 'A Geologic Time Scale 2012' by Gradstein et al. (2012); those for the Lower Pleistocene, Permian, Triassic and Cretaceous were provided by the relevant ICS subcommissions.

Coloring follows the Commission for the Geological Map of the World (http://www.ccgm.org)

Chart drafted by K.M. Cohen, S.C. Finney, P.L. Gibba

To cite: Cohen, K.M., Finney, S.C., Gibbard, P.L. & Fa ed)
The ICS International Chronostratigraphic Chart. Epi

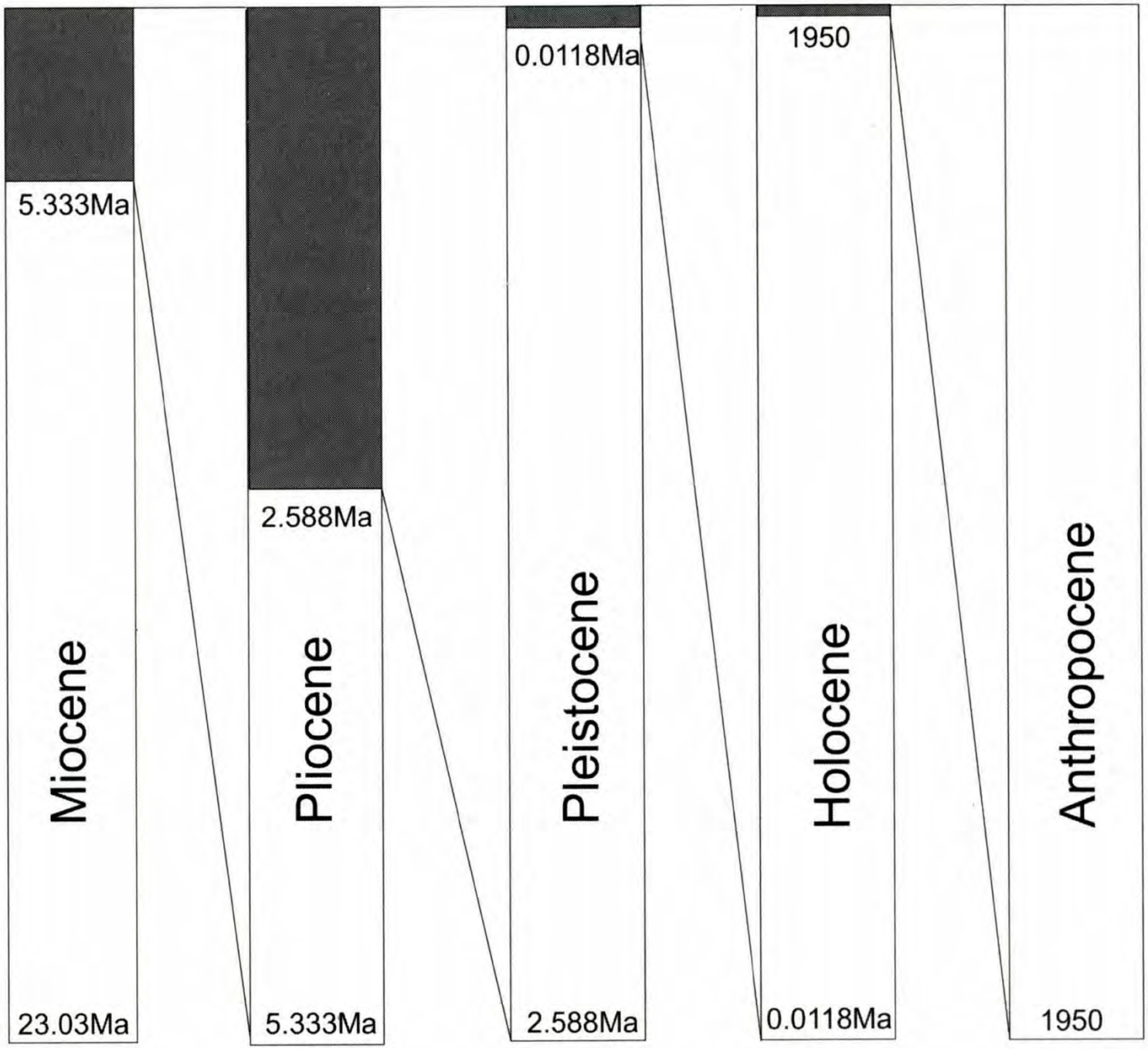
URL: http://www.stratigraphy.org/ICSchart/Chronostra

UPV-EHU

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Subseries / Subepoch	Stage / Age	GSSP	Numerical age (Ma)
Phanerozoic	Cenozoic	Quaternary	Anthropocene		to be named		present
			Holocene	U/L	Meghalayan		mid-20th century
				M	Northgrippian		0.0042
				L/E	Greenlandian		0.0082
			Pleistocene	U/L	to be named		0.0117
				M	to be named		0.126
				L/E	Calabrian		0.773
					Gelasian		1.80
							2.58

(Zalasiewicz, J. et al., 2017. Anthropocene, 19, 55-60)

UPV-EHU

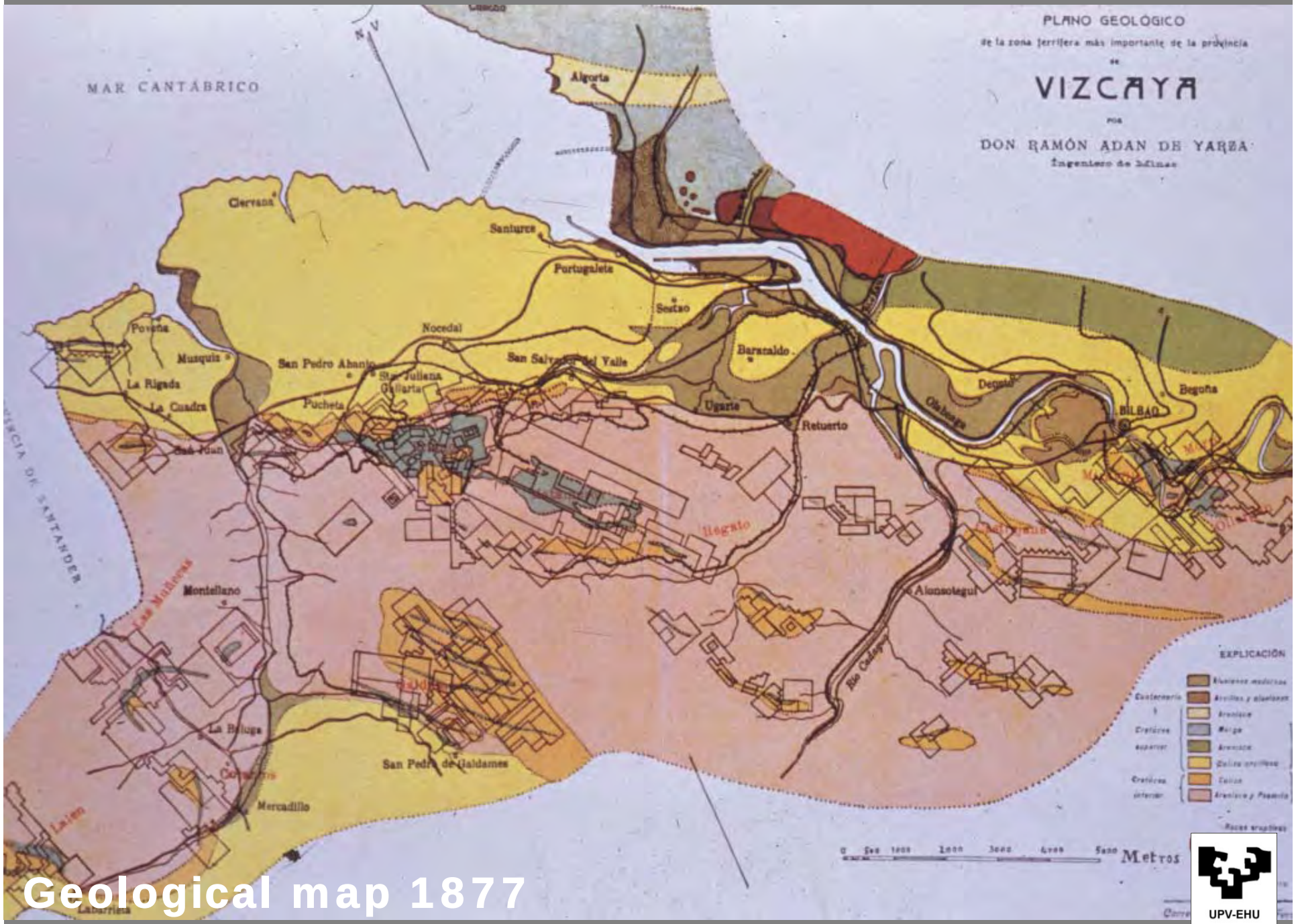


(Zalasiewicz, J. et al., 2014. Geological Society of London Special Publications, 395, 39-53)

UPV-EHU

Bilbao estuary

UPV-EHU



Geological map 1877

UPV-EHU


Sestao 1863
UPV-EHU


Sestao 1892
UPV-EHU


Sestao 1900
UPV-EHU

Barakaldo 1976

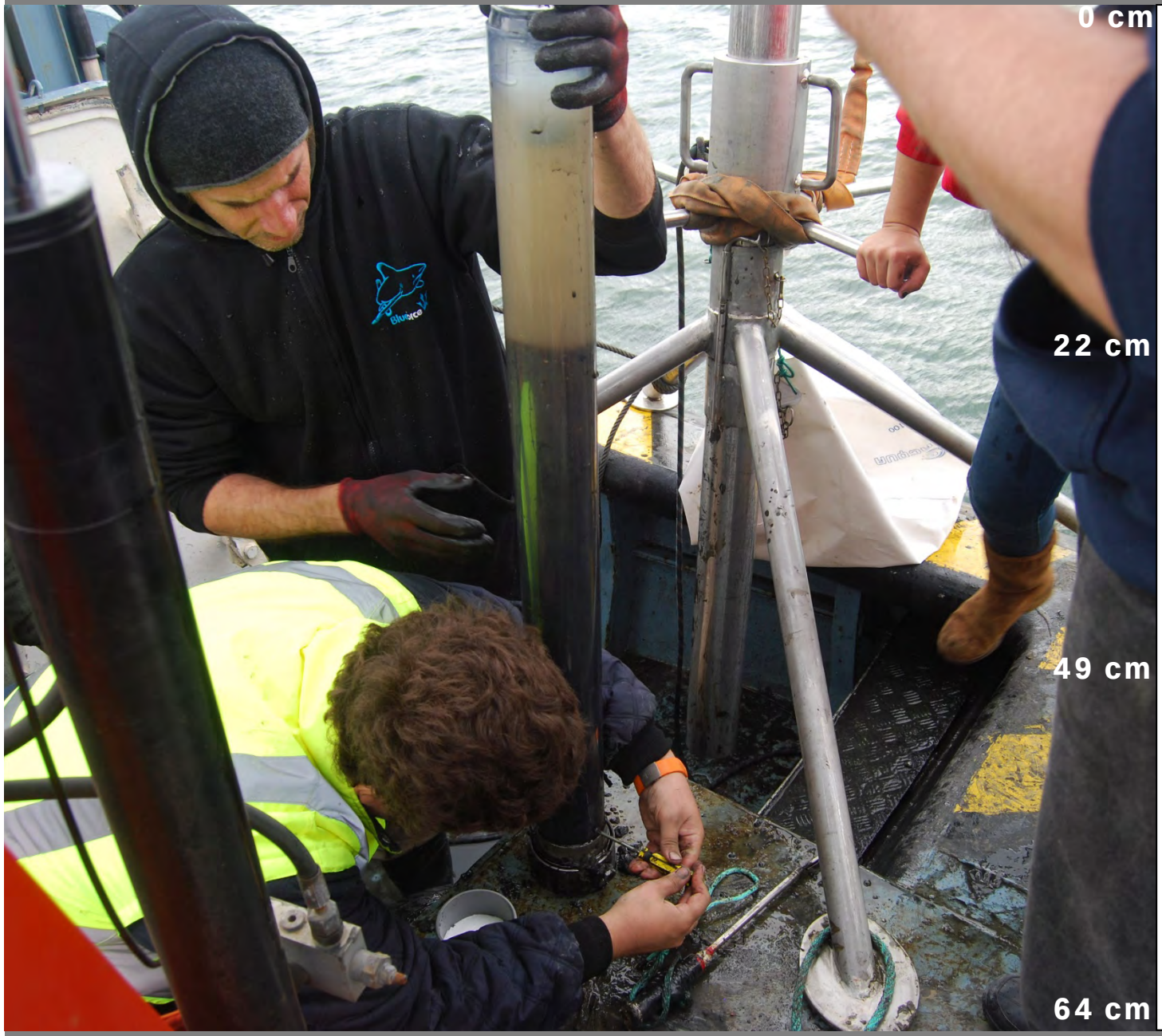
UPV-EHU

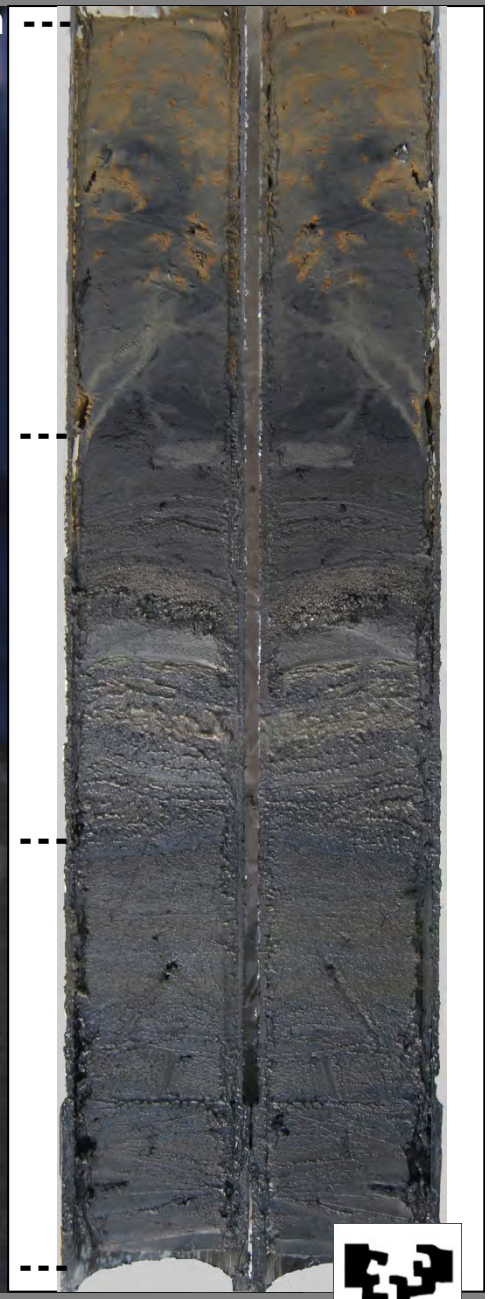

Zorroza 1970s
UPV-EHU


Abra bay in 1970s
UPV-EHU

Abra bay (Getxo)

UPV-EHU

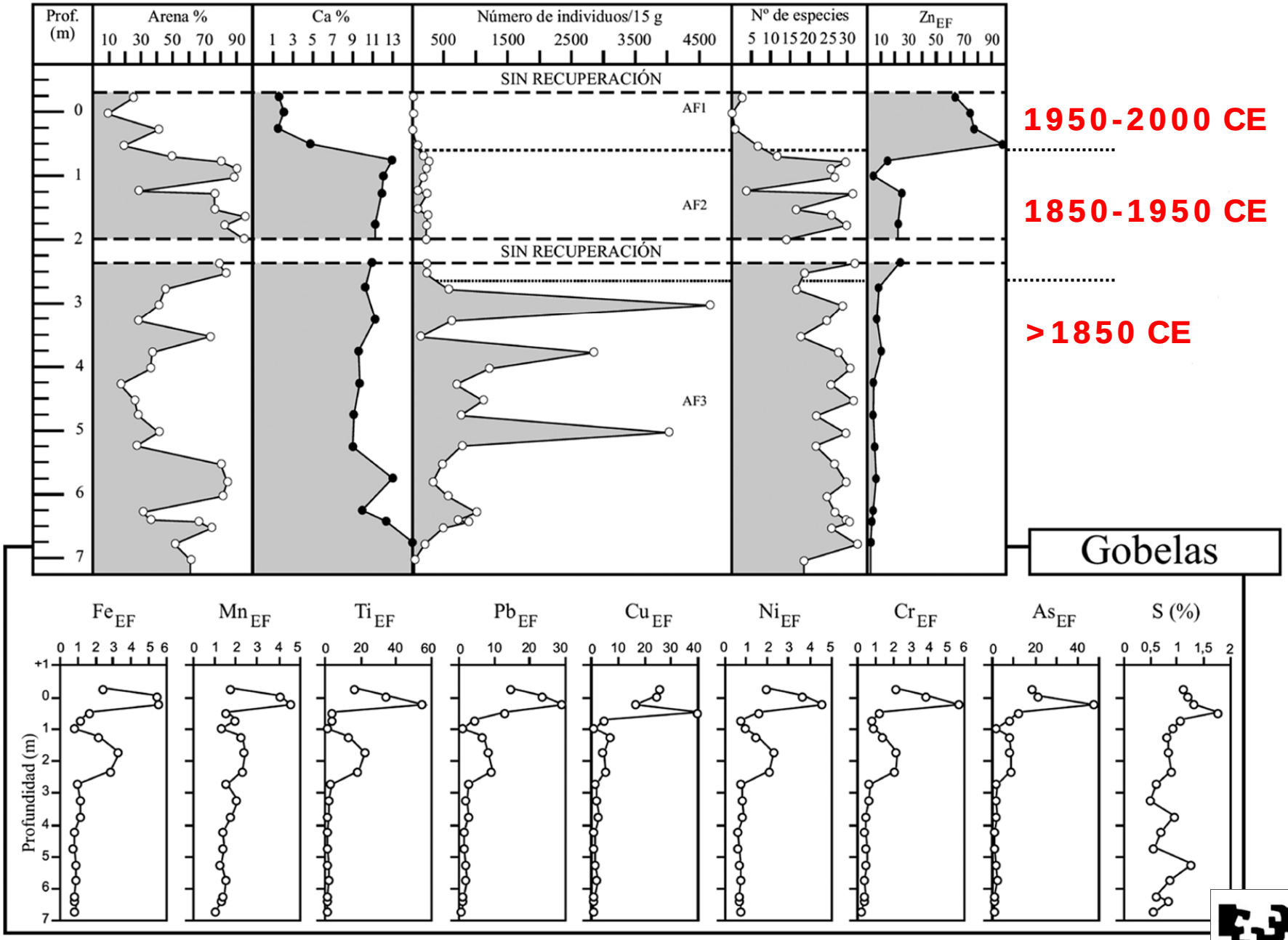




Core extraction

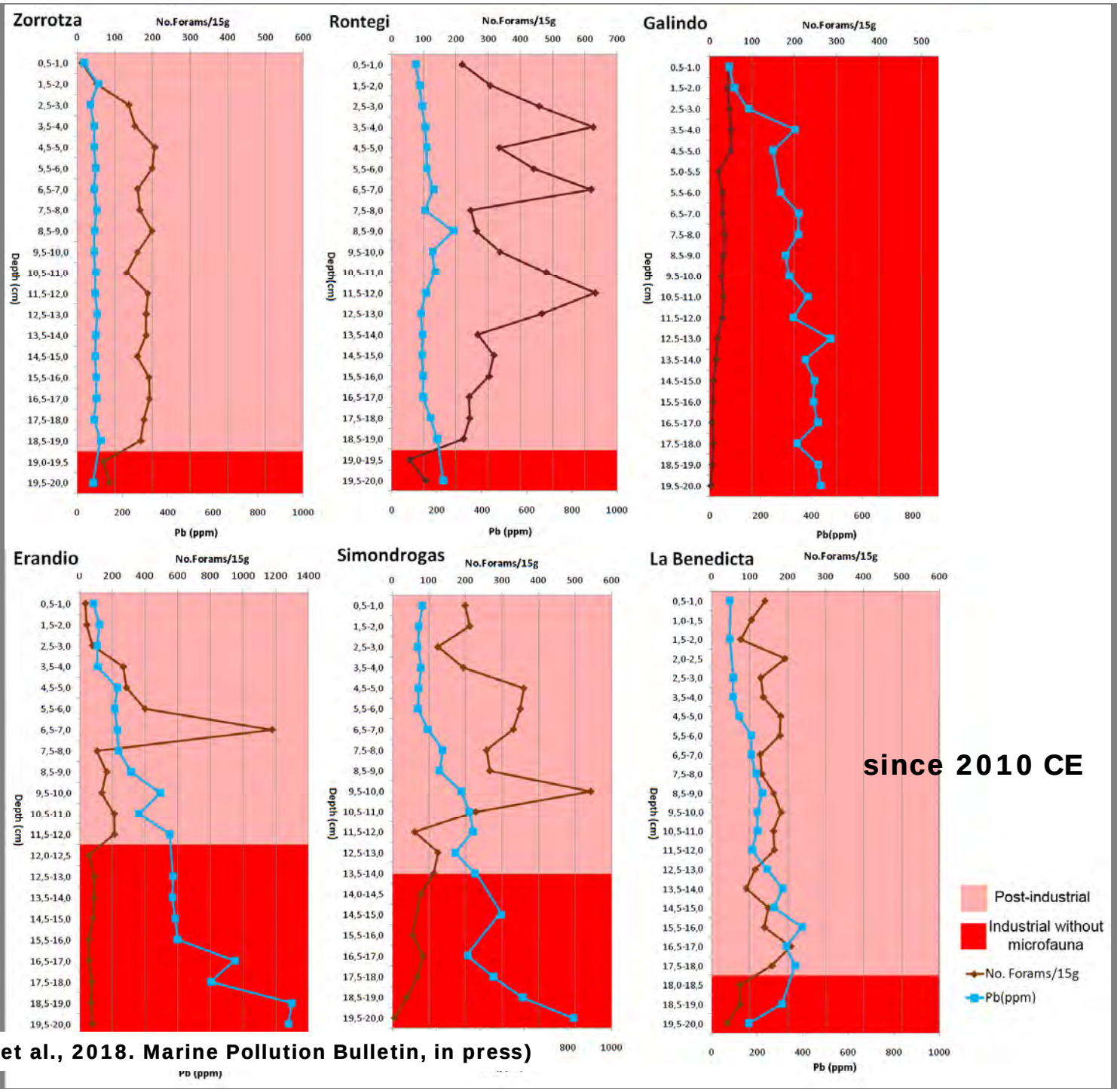
Abra 1 core

UPV-EHU



(Cearreta, A. et al., 2002. Marine Pollution Bulletin, 44, 487-503)

UPV-EHU



since 2010 CE

(Irabien, M.J. et al., 2018. Marine Pollution Bulletin, in press)

UPV-EHU

Tunelboca beach (Getxo)

UPV-EHU

(Goitia, J., 2012. Unpublished MSc dissertation UPV/EHU)

UPV-EHU

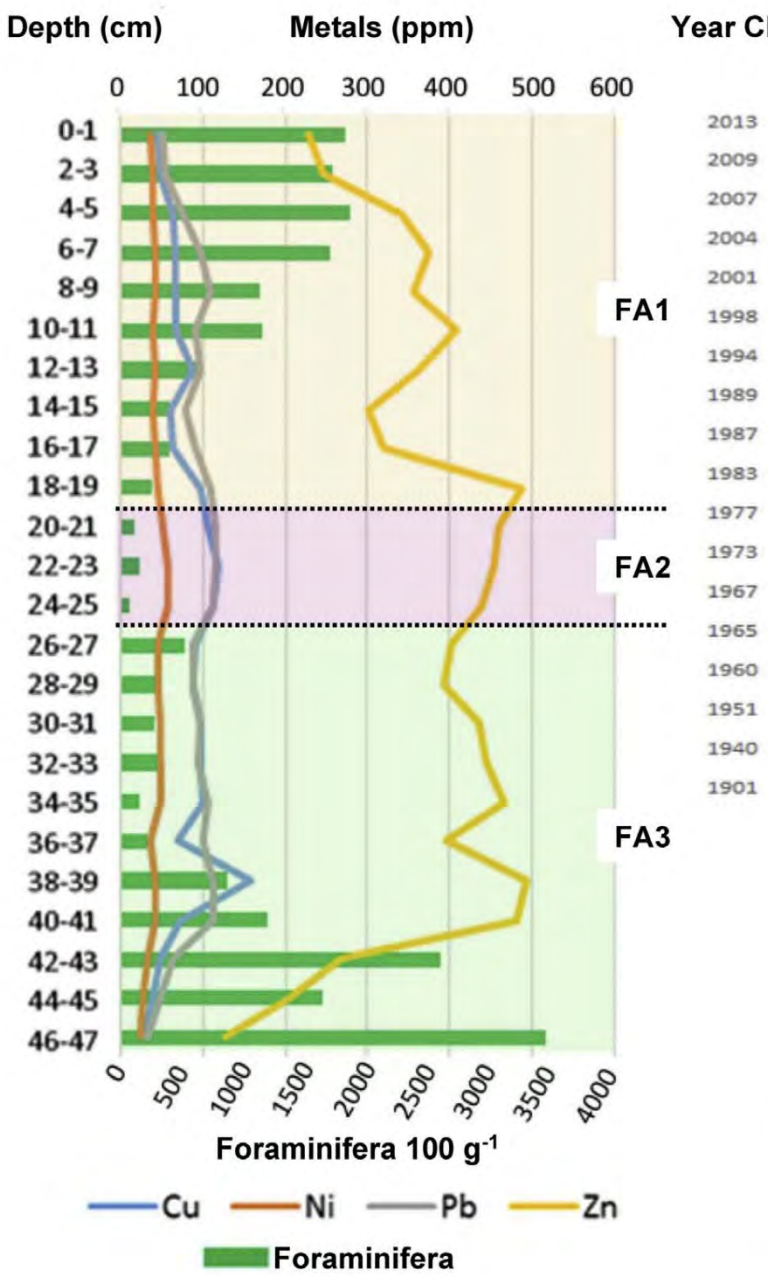
Technofossils (refractory bricks)

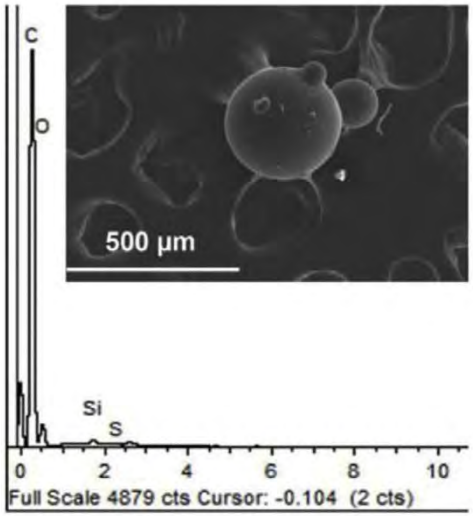
UPV-EHU

Technofossils (plastics)

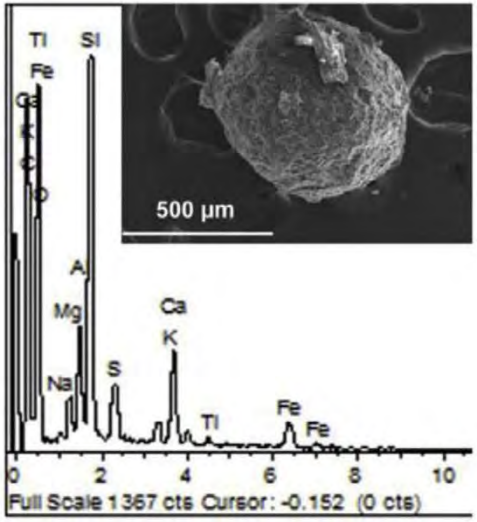
UPV-EHU

Zumaia 1 core

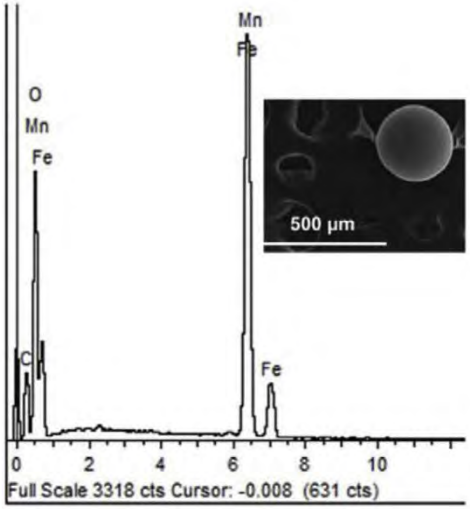




Polymeric spheroids from 1980s



Carbonaceous spheroids from 1900s

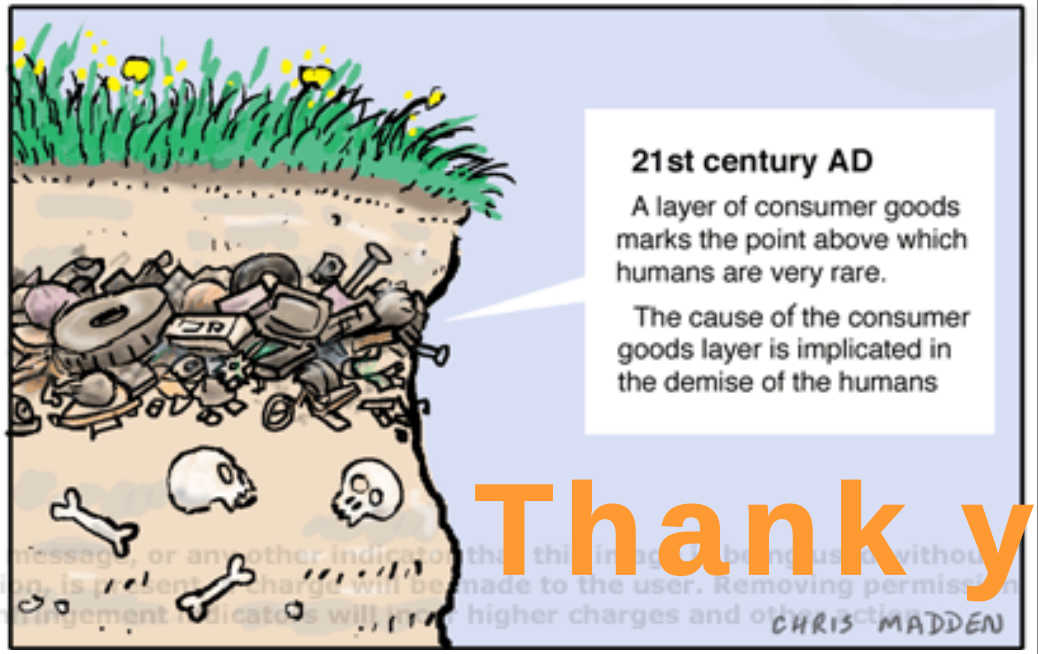


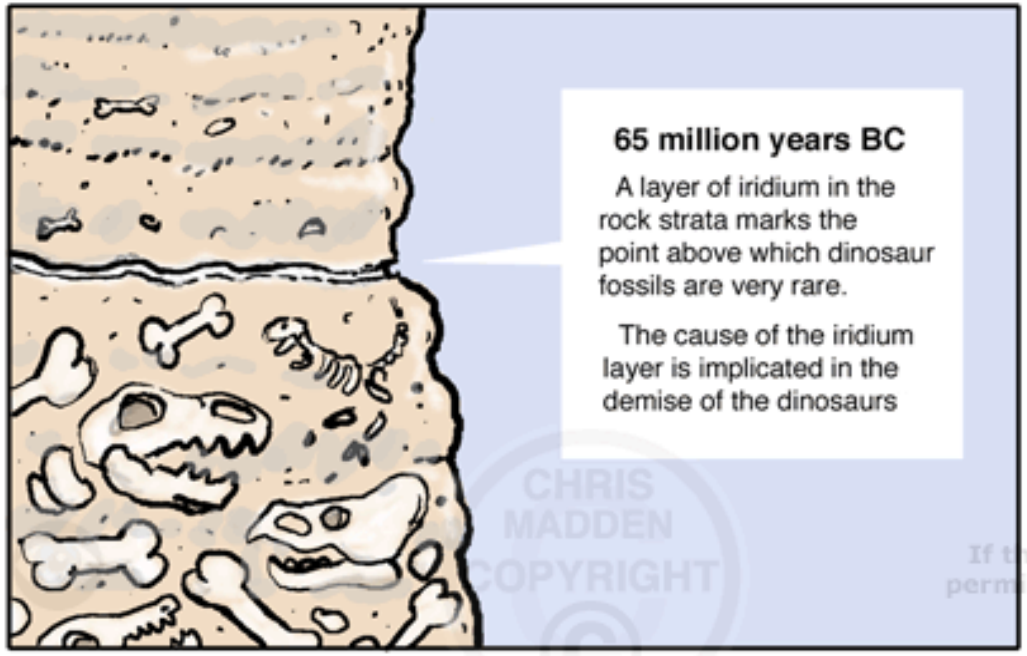
Iron spheroids from 1960s

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

UPV-EHU

LESSONS FROM THE FOSSIL RECORD





Thank you!

UPV-EHU