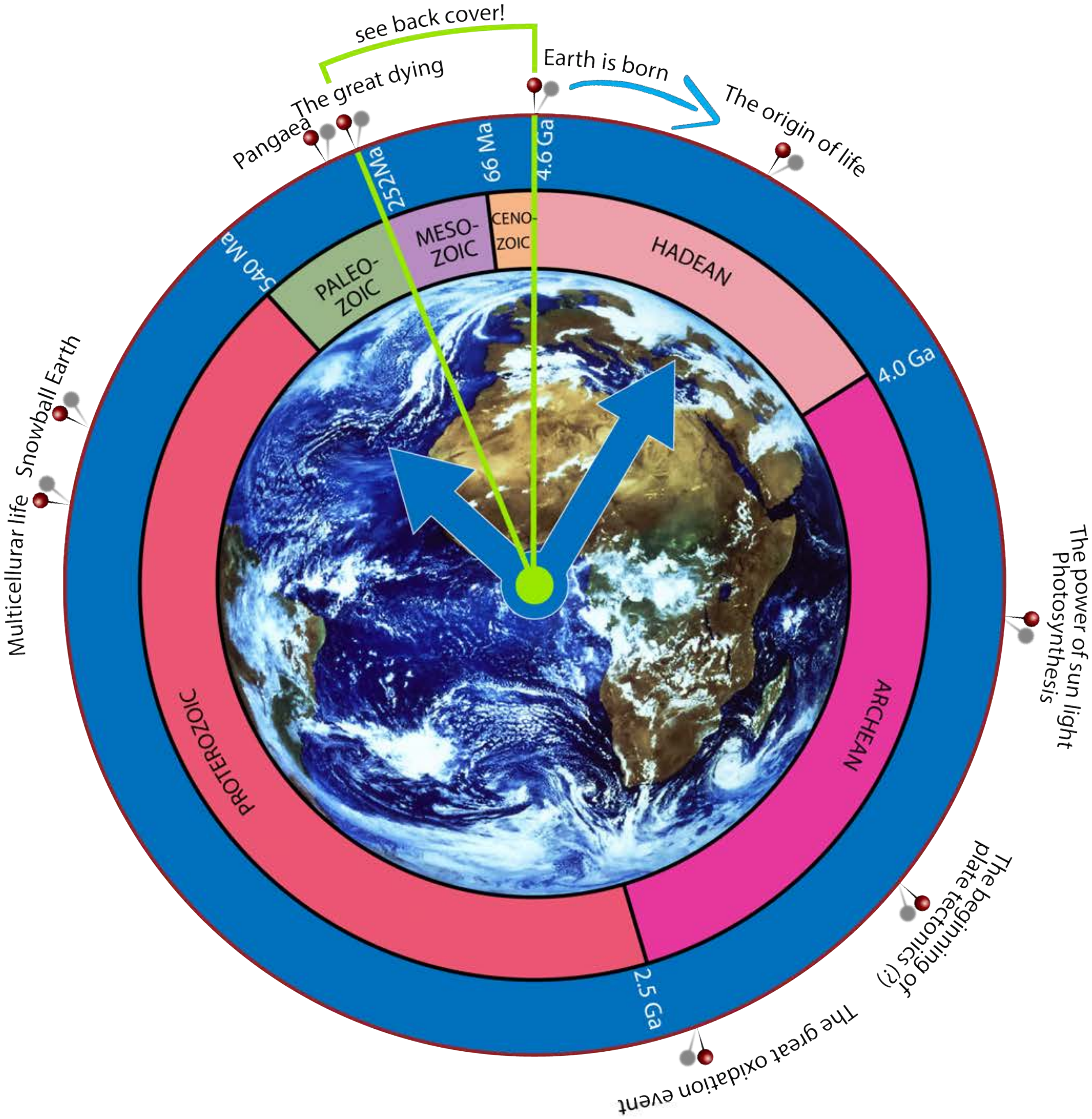
European Geosciences Union

GIFT – Geosciences Information For Teachers

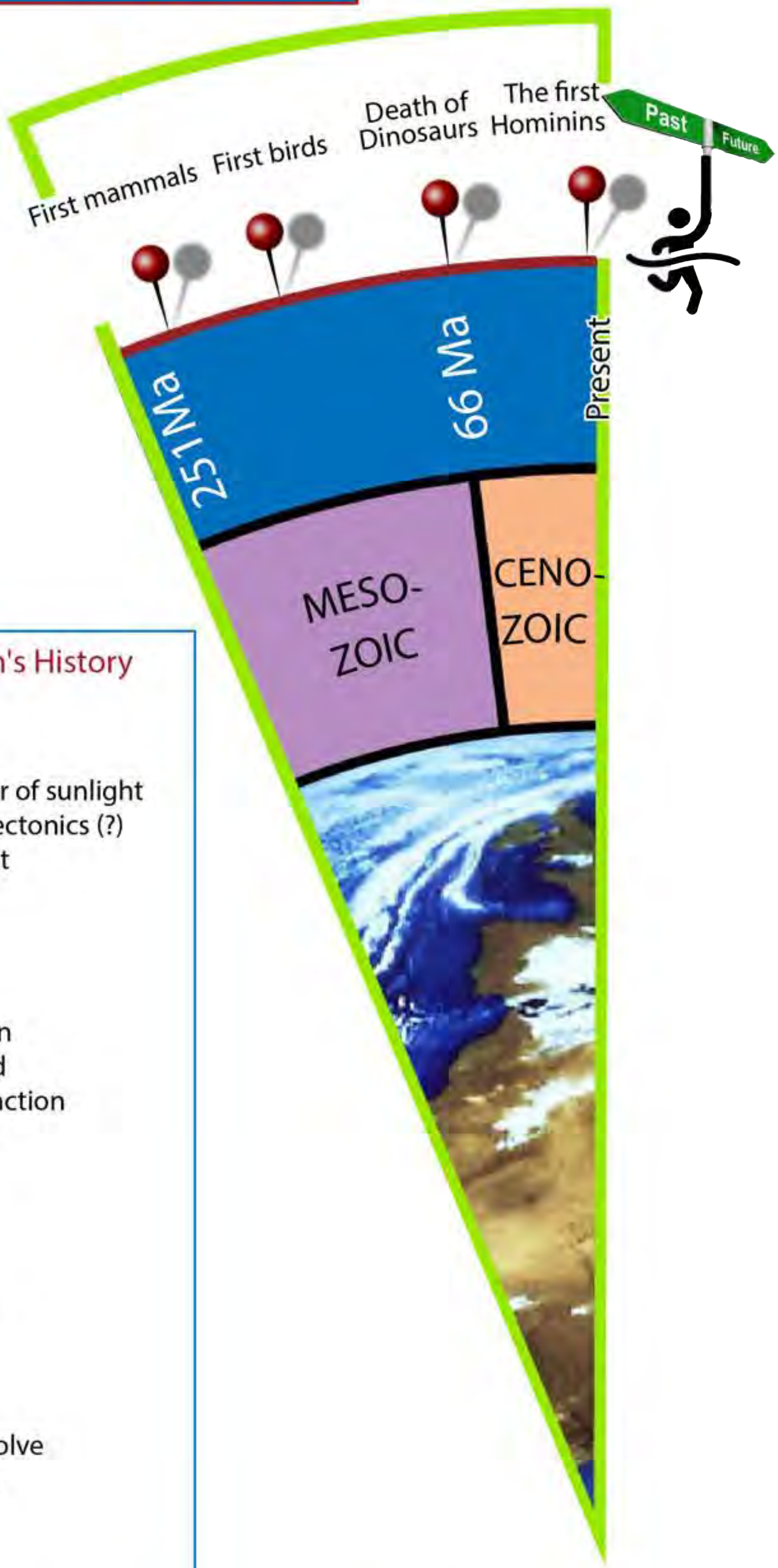


GIFT 2018

MAJOR EVENTS THAT SHAPED THE EARTH

Vienna, Austria, 9-11 April 2018

European Geosciences Union
GIFT – Geosciences Information For Teachers



The 25 Biggest Turning Points in Earth's History

1) 4.5b years ago: Earth is born
2) 4-3.5b years ago: The origin of life
3) 3.4 b years ago: Life harnesses-the power of sunlight
4) 3.0b years ago: The beginning of plate tectonics (?)
5) 2.4b years ago: The great oxidation event
6) 2-1b years ago: Endosymbiosis
7) 1.2b years ago: The first sex (?)
8) 1.0b years ago: Multicellular life
9) 850-635m years ago: Snowball Earth
10) 535m years ago: The Cambrian Explosion
11) 465m years ago: Plants colonise the land
12) 460-430m years ago: The first mass extinction
13) 375m years ago: Fish that walk on land
14) 320m years ago: Dawn of the reptiles
15) 300m years ago: Pangaea
16) 252m years ago: The great dying
17) 220m years ago: The first mammals
18) 201m years ago: The Triassic extinction
19) 160m years ago: The first birds
20) 130m years ago: Flowers flower
21) 65m years ago: Death of dinosaurs
22) 60-55m years ago: The first primates evolve
23) 32-25m years ago: Supercharged plants
24) 13-7m years ago: The first hominins
25) 200,000 years ago: The human race

http://www.bbc.com/earth/bespoke/story/20150123-earths-25-biggest-turning-points/

GIFT 2018
MAJOR EVENTS THAT SHAPED THE EARTH
Vienna, Austria, 9-11 April 2018

Dear Teachers,

Welcome to the 25th GIFT workshop of the European Geosciences Union. This year the workshop will bring together 82 teachers from 22 different countries around the general theme of "**Major events that shaped the Earth**". We hope that the choice of this theme will be useful to all of you, as teachers of Earth Sciences, Chemistry, Physics, Biology, Geology or Geography in your classroom lessons.

Among these major events, the first is, of course, the formation of the Earth itself some 4,56 billion years ago, very shortly after the formation of the solar system. **Marc Chaussidon**, from the Institut de Physique du Globe, France, will tell us this fascinating story.

Then, **Stephen Mojzsis** of the University of Colorado, USA, will describe the conditions that led to the emergence of life, and this will be followed by a description of the development up of the Earth's magnetic field and its contribution to the preservation of life by **John Tarduno** from the University of Rochester, USA.

You are probably aware that the Earth's crust is divided into eight major 'tectonic' plates that slide over, under or alongside each other, building mountains, creating ocean basins and causing earthquakes. But when did this fundamental process begin? This is a difficult question to answer, because the processes of plate tectonics themselves mask their original story. The recycling of the Earth's crust is so efficient that almost every trace of the evidence older than some 200 million years is lost. **Massimo Mattei**, from the University of Roma Tre, Italy, will tell us about this critical development of our planet.

About 2.3 billion years ago, a major change occurred in the atmosphere when it became increasingly rich in oxygen, causing a revolution in all living species. **Ariel Anbar**, from the Arizona State University, USA, will tell us all about this change. **Isabelle Ansorge**, from the University of Cape Town, South Africa, will then step in to describe how the oceans were shaped and what we can expect in the next 200 million years.

The story of mass extinction will then be explored by **David Bond**, of the University of Hull, UK, and **Christian Koeberl**, of the Natural History Museum and University of Vienna, Austria, who will respectively explore the Permian mass extinction and Cretaceous/Paleogene extinction and their causes. During these events a large number (up to 96%) of existing species rapidly became extinct, so that it is difficult to see how Darwin's ideas of extinctions caused by competition between species can explain mass extinctions.

The new term "Anthropocene" has been proposed by Nobel Prize laureate Paul Crutzen to indicate a new "geological" era characterized by the major influence of humans on the evolution of the Earth. Chris Rapley, a climate scientist at University College London, UK, and former director of the Science Museum in London said: "The Anthropocene marks a new period in which our collective activities dominate the planetary machinery". In this GIFT workshop, we are very lucky to have **Reinhold Leinfelder,** Geologist from the Freie Universität in Berlin, Germany, and member of the Anthropocene Working Group, to tell us about this proposed geological period, in which humans are having a major influence over the evolution of the Earth.

Finally, **Francesco Sarti** and **Chris Stewart**, from the European Space Agency, will show how Earth observations from space have changed our knowledge of the Earth.

As in every GIFT Symposium, contributions by the attending teachers on activities that they have used in their classrooms are particularly welcome in the poster session called "**Science in**

tomorrow's classroom". The session features any type of pedagogic activity, not necessarily related to this year's theme of the GIFT workshop. Also, during the first afternoon of the workshop, **Diane Carrer** and **Jérémy Camponovo** from the Centre International de Valbonne, France, and **Chris King**, of the Committee on Education of EGU will present different hands-on activities, through the "Crater Impact Lab", or in the 'Teaching the Structure of the Earth and Plate Tectonics' workshop respectively. You will experience both and we hope that you will be interested in testing and evaluating these activities for the eventual use in your own classroom.

Furthermore, **Francine Brondex**, a freelancer in education and outreach, and **Eric Bataillou**, from the de Grasse Elementary School at Bar sur Loup, invite you to follow, via email, their exploratory tour of French Antarctic Islands, on board the R/V Marion Dufresne, **Manuel Pubellier**, of the École Normale Supérieure in Paris, and **Serge Riazanoff** of the Visio Terra Company, will demonstrate a new tool for teaching geology and geophysics, **Maja Sojtaric** and colleagues will introduce you to Ice Sheet Evolution in the Arctic, and **Glaiza Reobilo**, from the Philippine High School in the Bicol region and **Carlo Laj** from the Committee on Education of EGU, will invite you to follow their Oceanographic cruise in the Philippine Sea on board the R/V Marion Dufresne, first via email, then later using the video which will be produced on board and will be freely distributed to all the teachers who request a copy.

On the day preceding the workshop, **Mathias Harzhauser** and **Herbert Summesberger** invite you for a visit of the Natural History Museum in Vienna, one of the most outstanding museums in the world. For those of you who can stay for Wednesday afternoon, Herbert will also take you on a geological trail here in Vienna, from Theresa's monument to St. Stephens Cathedral.

The GIFT workshop is sponsored not only by EGU, but also by several science organizations. We would like to continue to offer teachers the opportunity to attend GIFT and similar workshops, but this depends upon us being able to show our sponsors that teachers have used the GIFT information and educational approaches in their daily teaching, or as inspiration for teaching geoscience in new ways in their schools.

Therefore, we ask you:

1. To complete the evaluation forms as soon as possible and email them back to us;
2. To make a presentation of your experiences of GIFT to a group of your teaching colleagues sometime after you return from EGU, and
3. To send us reports and photographs about how you have used the GIFT information in your classrooms. We also encourage you to write reports on the GIFT workshop in publications specifically intended for geoscience, science and geography teachers.

Information on past GIFT workshops is available here:
http://www.egu.eu/education/gift/workshops
where you can find the brochures (pdf) and the slides of the different presentations given at the GIFT workshops over the past 12 years. Since 2009, we have also included web-TV presentations, which may be freely downloaded and used in your classrooms. By clicking on
http://www.egu.eu/education you will find out about all the educational activities of the European Geosciences Union.

Please enjoy your GIFT workshop in Vienna! If you do not fully enjoy your time with us, please tell us to help us to do better next time. If, as we hope, you do enjoy attending this GIFT workshop, please tell your schools, friends and colleagues and encourage them to come to future GIFT workshops. If you are using social media, please tag your posts or pictures @Eurogeosciences #GIFT2018 #EGU18.

The Committee on Education
European Geoscience Union

Acknowledgements

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Education en sciences de la Terre

And we thank all the speakers who have contributed to this educational workshop and their institutions!

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Program

European Geosciences Union – General Assembly

GEOSCIENCE INFORMATION FOR TEACHERS (GIFT) WORKSHOP

Vienna, 8-11 April 2018

'Major events that shaped the Earth'

Sunday April 8, 2018

16:00 - 18:00 **GUIDED TOUR OF THE NATURAL HISTORY MUSEUM VIENNA**
Herbert Summesberger and Mathias Harzhauser
Natural History Museum Vienna

Monday April 9, 2018

Chairperson: Carlo Laj, EGU Committee on Education

08:30 – 08:45 **WELCOME!**
Jonathan Bamber
President of EGU

08:45 – 09:15 **INTRODUCTION TO THE 2018 GIFT WORKSHOP**
Carlo Laj
EGU Committee on Education

9:15 – 10:00 **THE FIRST MILLION YEARS OF THE SOLAR SYSTEM: FROM DUST TO PLANETS**
Marc Chaussidon
Institut de Physique du Globe, Paris, France

10:00 – 10:30 COFFEE BREAK

Chairperson: Francesca Funiciello, EGU Committee on Education

10:30 – 11:15 **THE EMERGENCE OF LIFE**
Stephen J. Mojzsis
University of Colorado, CO, USA

11:15 – 12:00 **WHEN DID THE EARTH'S MAGNETIC FIELD START, AND HOW HAS IT CONTRIBUTED TO THE PRESERVATION OF LIFE?**
John A. Tarduno
University of Rochester, NY, USA

12:00 – 12:15 **INSTRUCTIONS FOR THE POSTER SESSION EOS03**
Eve Arnold
EGU Committee on Education

12:15 – 14:00 LUNCH (SANDWICHES) AND TOUR OF THE EGU EXHIBITION

Chairperson: Jean Luc Berenguer, EGU Committee on Education

14:00 -14:45	**PLATE TECTONICS: THE SCIENTIFIC REVOLUTION THAT REVEALED HOW OUR PLANET WORKS** Massimo Mattei Università degli Studi Roma Tre, Rome, Italy
14:45– 18:45	**HANDS-ON ACTIVITIES** (two groups alternating)
Group 1	**TEACHING THE STRUCTURE OF THE EARTH AND PLATE TECTONICS** Chris King EGU Committee on Education
Group 2	**CRATER IMPACT LAB** Diane Carrer and Jérémy Camponovo International High School Valbonne, France

Tuesday April 10, 2018

Chairperson: Steve Macko, EGU Committee on Education

08:30 - 09:15	**THE GREAT OXIDATION EVENT, 2.3 BILLION YEARS AGO** Ariel Anbar Arizona State University, Arizona, USA
09:15 – 10:00	**SHAPING THE EARTH – FROM PANGAEA…AND POSSIBLY BACK AGAIN!** Isabelle Ansorge University of Cape Town, South Africa

10:00 – 10:30 COFFEE BREAK

Chairperson: Friedrich Barnikel, EGU Committee on Education

10:30 – 11:15	**HOW VOLCANIC ERUPTIONS CAUSED EARTH'S GREATEST MASS EXTINCTION AND WHAT THAT TELLS US ABOUT THE FUTURE** David P.G. Bond University of Hull, United Kingdom
11:15 – 12:00	**IMPACT EVENTS IN EARTH HISTORY: THE CRETACEOUS-PALEOGENE BOUNDARY EJECTA LAYER AND ITS SOURCE CRATER AT CHICXULUB** Christian Koeberl Natural History Museum and University of Vienna, Austria
12:00 – 14:00	**LUNCH (SANDWICHES) AND OUTDOOR GEOSCIENCE ACTIVITIES (optional)**

Chairperson: Eve Arnold, EGU Committee on Education

14:00 – 15:00 **VIRTUAL TOUR: ANTARCTIC ISLANDS UPDATE**
Francine Brondex
Freelancer in Education and Outreach
Eric Bataillou
Amiral de Grasse Primary School, Bar sur Loup, France

15:00 – 19:00 **EOS3 – POSTER SESSION**

Wednesday April 11, 2018

Chairperson: Annegret Schwarz, EGU Committee on Education

08:30 - 09:15 **WELCOME TO THE ANTHROPOCENE – THE EARTH IN OUR HANDS**
Reinhold Leinfelder
Free University, Berlin, Germany

09:15 - 10:00 **HOW EARTH OBSERVATION (EO) FROM SPACE CHANGED OUR KNOWLEDGE OF THE PLANET**
Francesco Sarti and Chris Stewart
European Space Agency / ESRIN, Frascati, Italy

10:00 – 10:30 COFFEE BREAK

Chairperson: Phil Smith, EGU Committee on Education

10:30 – 11:00 **VtWeB, A NEW SITE FOR TEACHING GEOLOGY AND GEOPHYSICS**
Manuel Pubellier
Ecole Normale Supérieure, Paris, France
Serge Riazanoff
Visio Terra, Champs-sur-Marne, France

11:00 – 11:30 **ICE SHEET EVOLUTION IN THE ARCTIC**
Maja Sojtaric, Henry Patton, Alun Hubbard L.
UiT The Arctic University of Norway
Mona Holmø
Nordnorsk vitensenter Tromsø, Science centre, Tromsø, Norway

11:30 – 12:00 **VIRTUAL TOUR: 'TEACHERS-AT-SEA' IN THE PHILIPPINES SEA**
Glaiza Reobilo and Carlo Laj
Philippine Science High School, Bicol Region Campus, Philippines
EGU Committee on Education

12:00 LUNCH (SANDWICHES)

GOOD BYE!

Optional:

14:00 - 15:30 **GEOLOGICAL TRAIL FROM MARIA THERESA'S MONUMENT TO ST. STEPHEN'S CATHEDRAL**
Herbert Summesberger, Natural History Museum Vienna, Austria

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Speakers

GUIDED TOUR OF THE NATURAL HISTORY MUSEUM VIENNA

Herbert Summesberger and Mathias Harzhauser
Natural History Museum Vienna

Standing on each side of the bronze elephant (an artwork of the Viennese artist Gottfried Kumpf) in front of the entrance, our two hosts for the visit to the Natural History Museum Vienna:

Mathias Harzhauser, on the left, Head of the Department of Geology and Palaeontology, has earned his degrees from the University of Vienna and has been employed by the NHM after his Master's thesis. His PhD thesis deals with the Palaeoceanography of the Oligocene and Lower Miocene Gastropoda of the Eastern Mediterranean and the Western Indo-Pacific.

Herbert Summesberger, on the right, has earned his degrees from the University of Vienna. His PhD thesis deals with structural geology, stratigraphy and palaeontology in the Northern Calcareous Alps. He has organized several international symposia and is the leader of the Working Group on Geosciences, School and Public Relations of the Austrian Geological Society. Retired since 2004, he is a member of the Board of the Friends of the Museum of Natural History, and organizes exhibitions and seminars for High School teachers. He has also written high school books and a Vienna city guide for building and decoration stones.

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CAREER

• CNRS researcher since 1988, at Centre de Recherches Pétrographiques et Géochimiques (CRPG, Nancy, France), from 1988 to 2014 and at Institut de Physique du Globe de Paris (IPGP, Paris, France) since 2014.
• Professor (1/3 service) at Ecole Polytechnique in Palaiseau (Department of Physics) since 2008.
• Director of Institut de Physique du Globe de Paris since 2016.

RESEARCH INTERESTS

My recent research activities cover two different domains: early Earth and cosmochemistry. I am for instance studying the Si and O isotopic compositions of precambrian cherts to try to better constrain variations of seawater temperature during this period. In cosmochemistry I am especially interested in the first 2-3 Myrs of the solar system, a key period which can be studied through the analysis of various isotopic composition and short-lived radionuclides in meteoritic components.

PUBLICATIONS AND SERVICES

Dauphas N. & Chaussidon M. (2011) A perspective from extinct radionuclides on a young stellar object: the Sun and its accretion disk. Annual Rev. Earth Planet. Sci. 39, 351-386.
Chaussidon M. & Liu M.-C. (2015) Early Solar System processes: from nebular gas to the precursors of the Earth. In "The early Earth: accretion and differentiation", Eds J. Badro & M. Walter Geophysical Monograph 212, p 1-26.

AWARDS AND HONORS

Fellow of American Geophysical Union (2017), Fellow of the Meteoritical Society (2010), ERC advanced grant (2008-2013), Geochemical Fellow from the Geochemical Society and the European Association of Geochemistry (2007), Asteroid 7048 named Chaussidon by the International Astronomical Union (2002), CNRS silver medal (2002), Houtermans medal European Association of Geochemistry (1995).

THE FIRST MILLION YEARS OF THE SOLAR SYSTEM: FROM DUST TO PLANETS

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Recent advances in the study of meteorites, in the observation of young forming stars, and in astrophysical modeling of accretion disks, allow to find out how our solar system was formed and how the planets were constructed. All the chemical elements that constitute the Earth entered the forming solar system as a mixture of grains and gas, originating from the gravitational collapse of a dense region of the parent interstellar molecular cloud. All the major rock forming elements, except oxygen, were hosted by these grains. The formation of the Earth is the endpoint of a number of processes starting from this initial mixture that underwent very high temperature at proximity to the young Sun giving birth upon cooling, at various heliocentric distances, to a new generation of solids, the "true solar system solids". These solids were accreted together in the accretion disk to form the first rocks of the solar system and then upon further accretion between bigger objects a succession of bodies of different types and different sizes (Fig.1)

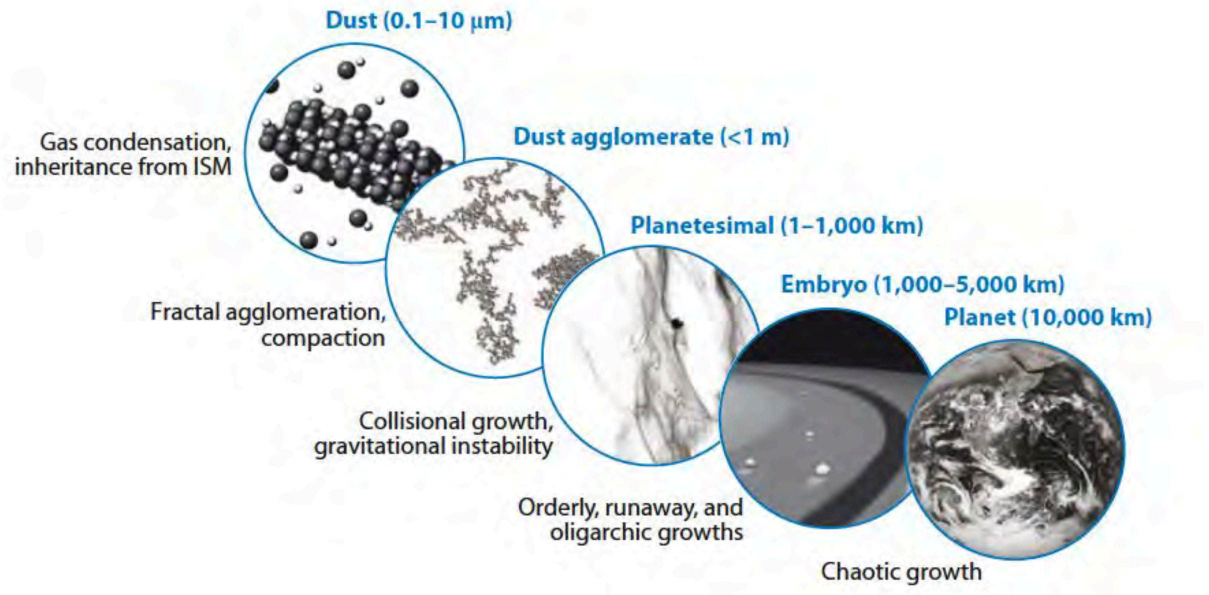

Figure 1: Chain of processes giving rise to terrestrial planets in the solar accretion disk. Dust made by condensation from the gas agglomerates to form the first rocks, which then undergo a series of accretion processes making successively planetesimals, embryos and planets (Fig from Dauphas and Chaussidon, 2011).

Meteorites are fragments of asteroids that are present in the so-called asteroidal belt situated in between Mars and Jupiter. These asteroids are "survivors": they are samples of the numerous planetesimals that populated the accretion disk during the first few million years of the Solar system, a time when the terrestrial planets did not exist yet. Among these meteorites some have compositions indicating that they are more primitive than others. At variance with the differentiated meteorites that originate from bodies having undergone metal-silicate differentiation (formation of a core) or silicate-silicate differentiation (formation of a crust), the primitive meteorites have a composition showing that they are "sediments"

which accumulated in the accretion disk. They are in fact "fossils" of the first few million years of the solar system. The primitive meteorites are also named chondrites from the fact that some of them are dominantly constituted of micrometer to millimeter size silicate spherules (names chondrules) that experienced flash heating to temperatures up to ≈2000 K and subsequent rapid cooling and quench. These processes happened when the chondrules were "floating" in the accretion disk. Studies of the mineralogy, texture, chemical and isotopic composition of these chondrules allow to reconstruct their thermal histories, to determine their precursors in the disk and the processes that produced them. Together with chondrules, primitive meteorites contain Al-, Ca-rich inclusions (named CAIs) that are understood as being the result of condensation at high temperature of minerals from the gas in the inner regions of the accretion disk. Chondrules and CAIs are embedded in a matrix of very complex composition, mostly made of minerals stable at much lower temperature and hosting volatile components such as water.

Precise dating of the various components of primitive meteorites allow to give an absolute age for the solar system of 4.567 Gyrs and to show that their components were produced in the few first million years of the solar system. Dating of differentiated meteorites show that accretion processes started very early, the first planetesimals beginning to grow a few 100 kyrs only after the start of the collapse of the parent presolar cloud. Depending on their size and time of formation (which both govern the amount of radioactive heat available in these bodies for internal heating) these planetesimals underwent differentiation before being accreted together to form embryos. Mars is likely such an embryo which stopped its evolution at this time. The Earth is the result of numerous collisions between embryos (the mass of the Earth is 10 times that of Mars) that took place in the following ≈30 to ≈100 Myrs. The Moon is likely the byproduct of one of the last giant collisions that the Earth experienced. The Earth at that time was covered by an ocean of magma. The origin of this water is still controversial. Part of it is the result of degassing of the magmas produced by melting of the hydrated minerals that were present in the embryos parent to the Earth. A small fraction of water could also have been brought by late impacts of water-rich bodies such as comets. But a large fraction of water has likely been delivered to the Earth at the very end of its formation by the so-called late veneer. This terminates the period of formation of the Earth sensu stricto. The Earth after that started its geological history evolving as "a closed system", even though it experienced the late heavy bombardment approximately 3.8 Gyrs ago. The oldest minerals that have been found on Earth are coming from the western Australian craton. They are zircon grains dated at ≈4.4 Gyr that formed in rocks akin granites.

References

Dauphas N. & Chaussidon M. (2011) A perspective from extinct radionuclides on a young stellar object: the Sun and its accretion disk. Annual Rev. Earth Planet. Sci. 39, 351-386.

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RESEARCH INTERESTS

My work focuses on the overall physico-chemical considerations of the conditions for the origin of life on Earth and Earth-like planets.

PROFESSIONAL PREPARATION

University of California - Los Angeles	Postdoctoral Scholar	2000
Scripps Institution of Oceanography (UC San Diego)	Ph.D. Earth Sciences	1997
Boston University, Boston, Massachusetts	M.A. Geology	1992
Boston University, Boston, Massachusetts	B.A. Geology	1988

APPOINTMENTS

2017-present Chair, College of Arts & Sciences Council
2016-present Director, the Collaborative for Research in Origins (CRiO)
2000-present Assistant (2000), Associate (2007), Full (2014) Professor of Geology, CU Boulder
2015-present Visiting Professor, Earth-Life Science Institute, Tokyo Institute of Technology, Japan
2013-present Distinguished Professor, Hungarian Academy of Sciences, Budapest, Hungary
2011-2013 Professor-in-residence, Université Claude Bernard Lyon 1, France
2007-2008 Fulbright Visiting Professor of Geochemistry, CNRS-CRPG Nancy, France
2001-2008 Associate Director, University of Colorado Center for Astrobiology
1999-2000 Adjunct Assistant Professor of Geochemistry, University of California Los Angeles
1998-2000 NSF Earth Sciences Postdoctoral Fellow, University of California Los Angeles
1997-1998 President's Postdoctoral Fellow, UCLA
1998-2000 Asst. Researcher, Institute for Pure & Applied Physical Sciences, UCSD
1995-1997 NSCORT Graduate Research Fellow, Scripps Institution of Oceanography, UCSD
1993-1997 Graduate Research Assistant, Scripps Institution of Oceanography, UCSD
1992-1993 Research Associate, Scripps Institution of Oceanography, UCSD

TWO MOST RECENT RELEVANT PUBLICATIONS

Mojzsis, S.J., Abramov, O., Frank, E.A., Brasser, R., (2018) Thermal consequences to Mercury's mantle by impact bombardment. *Earth and Planetary Science Letters* 482, 1-9.

Kelly, N.M., Metcalf, J.R., Flowers, R.M., Mojzsis, S.J. (2018) Late accretion to the Moon recorded in (U-Th)/He zircon thermochronometry. *Earth and Planetary Science Letters* 482, 222-235.

THE EMERGENCE OF LIFE

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The physical chemical steps leading to life on Earth took place at a time when water/rock interactions on our planet were strongly influenced by effects common on the young planet, including impacts.

There is no direct measure of the influx of asteroids, comets and left-overs of planet formation in the first half billion years of our solar system. It is within this time, however, that life likely took hold on our planet. Geochemical evidence shows the presence of a hydrosphere and evolved crust within the first 150 Myr of Earth, and just as early (if not earlier) on Mars (Mojzsis et al., 2014; Roth et al., 2014).
Hence, the necessary prerequisites for life: (i) liquid water, (ii) energy resources, (iii) organic building blocks, and (iv) adequate time for the abiotic chemistry to reach the complexity of biology were present very early on. It makes sense to explore whether abundant extraterrestrial matter fed the planetary organic-chemical reactor that gave rise to life. With bulk average sulfur, carbon and phosphorus contents of chondritic meteorites (Fitoussi and Bourdon, 2012) as a rough guide for a range of possible compositions of material delivered to Earth (Lodders and Fegley, 1998) and Mars (Abramov and Mojzsis, 2016), we can compute ranges for exogenous sources conservatively leading to the accumulation of the bio-essential elements. We may never know How or Where life originated, but we can answer When: at least some time after ca. 4.4 billion years ago.

Useful references:
Abramov, O., Kring, D.A. and Mojzsis, S.J. (2013) The impact environment of the Hadean Earth. Chemie der Erde - geochemistry 73, 227-248.
Abramov, O. and Mojzsis, S.J. (2016) Thermal effects of impact bombardments on Noachian Mars. Earth and Planetary Science Letters (IN PRESS).
Bottke, W.F., Walker, R.J., Day, J.M.D., Nesvorny, D., and Elkins-Tanton, L. (2010) Stochastic late accretion to Earth, the Moon and Mars. Science 330, 1527-1530.
De Duve, C. (2005) Singularities. Cambridge University Press, Cambridge, U.K.
Fitoussi, C. and Bourdon, B. (2012) Silicon isotope evidence against an enstatite chondrite Earth. Science 335, 1477-1480.
Frank, E.A., Maier, W.D. and Mojzsis, S.J. (2016) Highly siderophile element abundances in Eoarchean komatiite and basalt protoliths. Contributions to Mineralogy and Petrology (IN PRESS).
Gaspar, A., Rieke, G.H., Su, K.Y.L., Balog, Z., Trilling, D., Muzzerole, J., Apai, D. and Kelly, B.C. (2009) The low level of debris disk activity at the time of the late heavy bombardment: A Spitzer study of Praesepe. Astrophysical Journal 697, 1578-1596.
Harrison, T.M. (2009) The Hadean crust: evidence from >4 Ga zircons. Annual Review Earth and Planetary Sciences 37, 479-505.
Holland, H.D. (1984) The chemical evolution of the atmosphere and oceans. Princeton University Press, Princeton, N.J.
Humayun, M., Nemchin, A.A., Zanda, B., Hewins, R.H., Grange, M., Kennedy, A., Lorand, J.-P., Göpel, C., Fieni, C., Pont, S., and Deldicque, D. (2013) Origin and age of the earliest martian crust from meteorite NWA 7533. Nature 503, 513-516.
Jacobsen, S.A., Morbidelli, A., Raymond, S.N., O'Brien, D.P., Walsh, K.J. and Rubie, D.C. (2014) Highly siderophile elements in Earth's mantle as a clock for the Moon-forming impact. Nature 508, 84-87.

Lodders, K. and Fegley, B. Jr. (1998) The planetary scientist's companion. Oxford University Press, Oxford, U.K.
Mojzsis, S.J. (2007) Sulphur on the early Earth. Developments in Precambrian Geology 15, 923-970.
Mojzsis, S.J., Harrison, T.M. and Pidgeon, R.T. (2001) Oxygen isotope evidence from ancient zircons for liquid water at Earth's surface 4,300 Myr ago. Nature 409, 178-181.
Mojzsis, S.J., Cates, N.L., Bleeker, W., Hopkins, M.D., Guitreau, M., Blichert-Toft, J., Trail, D. and Abramov, O. (2014) Component geochronology of the ca. 3920 Ma Acasta Gneiss. Geochimica et Cosmochimica Acta 133, 68-96.
Morbidelli, A. (2010) A coherent and comprehensive model for the evolution of the outer solar system. Comptes Rendus Physique 11, 651-659.
Nemchin, A.A., Humayun, M., Whitehouse, M.J., Hewins, R.H., Lorand, J.-P., Kennedy, A., Grange, M., Zanda, B., Fieni, C. and Deldicque, D. (2014) Record of the ancient martian hydrosphere and atmosphere preserved in zircon from a martian meteorite. Nature Geoscience 7, 638-642.
Roth, A.S.G., Bourdon, B., Mojzsis, S.J., Rudge, J.F., Guitreau, M. and Blichert-Toft, J. (2014) Combined 147,146Sm=143,142Nd constraints on the longevity and residence time of the early terrestrial crust. Geochemistry, Geophysics, Geosystems 15, DOI: 10.1002/2014GC005313.
Walker, R.J. (2009) Highly siderophile elements in the Earth, Moon and Mars: Update and implications for planetary accretion and differentiation. Chemie der Erde – geochemistry 69, 101-125.

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EDUCATION
1987 MS., Ph.D. (Geophysics), Stanford University, USA
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CAREER
2005-present Professor of Physics and Astronomy, University of Rochester
2000-present Professor of Geophysics, University of Rochester
1998-2006, 2016-present Chair, Department of Earth & Environ. Sciences, University of Rochester
1993-2000 Assistant/Associate Professor of Geophysics, University of Rochester
1990 Assistant Research Geophysicist, Scripps Institution of Oceanography
1989 National Science Foundation Postdoctoral Fellow, ETH, Zürich, Switzerland
1988 JOI/USSAC Ocean Drilling Fellow, Stanford University

RESEARCH INTERESTS
Studies of Earth's magnetic field and planetary habitability

PUBLICATIONS
Tarduno, J.A. and Hare, V., Does an anomaly in Earth's magnetic field portend a coming pole reversal, The Conversation, February 2017.
https://theconversation.com/does-an-anomaly-in-the-earths-magnetic-field-portend-a-coming-pole-reversal-47528

Tarduno, J.A. et al., Detecting the oldest geodynamo and attendant shielding from the solar wind: Implications for habitability, Physics of Earth and Planetary Interiors, 233, 68-87, 2014.
OPEN ACCESS: http://www.sciencedirect.com/science/article/pii/S0031920114001332

AWARDS AND HONORS
Fellow, American Association for the Advancement of Science (2003)
Fellow, John Simon Guggenheim Foundation (2006-2007)
Edward Peck Curtis Award for Excellence in Undergraduate Teaching (2007)
Fellow, American Geophysical Union (2007)
Honorary Professor, University of KwaZulu-Natal, South Africa (2014)
Price Medal, Royal Astronomical Society (2016)
Petrus Peregrinus Medal, European Geosciences Union (2017)

WHEN DID THE EARTH'S MAGNETIC FIELD START, AND HOW HAS IT CONTRIBUTED TO THE PRESERVATION OF LIFE?

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University of Rochester, Rochester, NY

The key component for planetary habitability D at least for life as we know it D is the survival of water, and a global magnetic field that can help prevent erosion of an atmosphere and loss of a hydrosphere. The presence of water remains the standard for defining the habitable zone. It is important to start with this tenet because the importance of magnetic fields is sometimes confused and posed as essential for *any* atmospheric preservation. Venus is the clear counter example, representing a planet without a global magnetic field produced in its core but with a thick atmosphere. But there the utility of the Venusian analog for habitability stops. Venus is bone dry. Its atmosphere represents the end product of extreme water loss. Below, I will review the timeline for the early Earth, key hypotheses bearing on the timing and nature of the Earth's magnetic field (the geodynamo), magnetic data recording the early field (the discipline of paleomagnetism) and close with comments on the importance of the geodynamo on the sustainability of habitability.

Theia Impact

The protoDEarth prior to the lunar forming impact may have hosted a dynamo, but for practical purposes the timeline for the beginning of the geomagnetic field starts with the collision of the MarsDsized impactor known as Theia (Figure 1), ~160 million years after the formation of the Solar System (the latter is typically assigned an age of 4.57 billion years).

Figure 1. *Artists rendition of the impact resulting in the formation of the Moon. Image courtesy of NASA.*

We cannot expect to have direct evidence of terrestrial magnetizations before or at this age because of the profound planetary transformation the impact caused. But the timing and nature of the lunar forming event is nevertheless important in that it sets the initial conditions which bear on dynamo generation and the earliest composition of the atmosphere. The timing is further important because at these very young solar system ages the rapidly rotating Sun would have bathed Earth in solar winds (a constant stream of mainly protons) at least 100 times more powerful than today, with the possibility of frequent giant solar flares and coronal mass ejections further affecting Earth. Magnetic fields associated with these solar winds could have provided "seed" fields for the start of Earth's own magnetic field.

We now believe the lunar-forming impact could have fostered the birth of Earth's magnetic field in at least 2 other ways. Prior to the impact, Earth's liquid iron core may have developed layers, and these layers would have inhibited convection which is essential for the generation of magnetic fields. The impact would have destroyed this layering. The great heating of the core produced by the impact could have also resulted in MgO being incorporated into the core liquid. As the core subsequently cooled, the precipitation of this MgO could have helped generate the magnetic field. This is important because the young Earth lacked a solid inner core, the continued formation of which provides a key energy source for driving the magnetic field of Earth today. So why are these events, so deep in time and within Earth's core so important for habitability? The reason is that the same solar winds that may have produced a seed for the earliest geodynamo also have tremendous erosive power, and they can potentially erode and transform an atmosphere, eventually robbing a planet of its water.

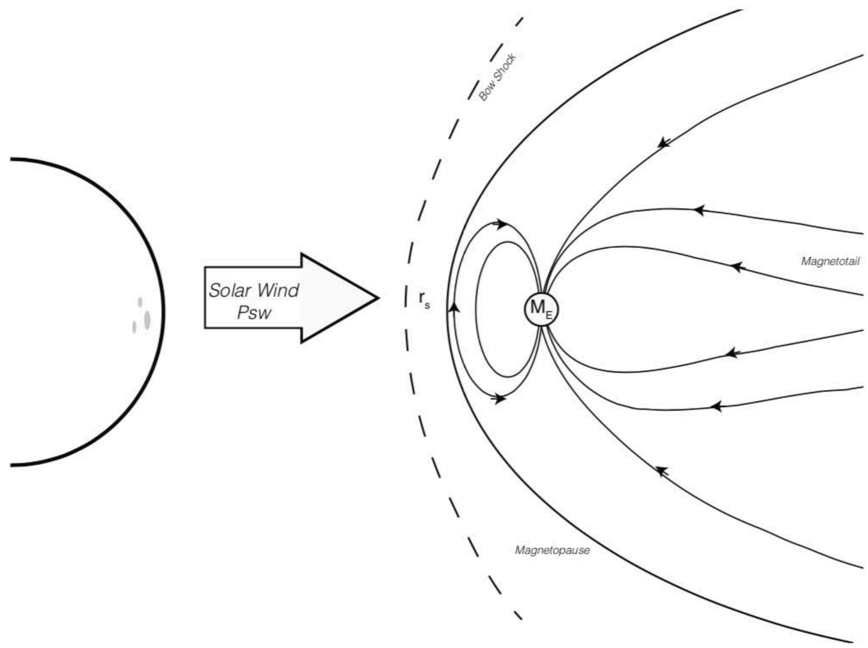

Figure 2. *Earth's magnetosphere (not to scale) is shaped by the interaction of the solar wind (having pressure Psw) and Earth's magnetic field (having a strength ME). The point where the solar wind pressure is balanced by the magnetic field is the magnetopause standoff distance (rs). From Tarduno et al., (2014).*

Magnetic fields can prevent this erosion by shielding. The interaction of Earth's magnetic field and the solar wind defines a cocoonDlike feature known as the magnetosphere (Figure 2). Today there is a pressure balance between the solar wind and Earth's magnetic fieldD the field stands off the solar wind to a distance of about 10 Earth radii (Re), a distance also referred to as the magnetopause. But what was the magnetopause in the past? And was the magnetic field actually present in the distant past?

The Hadean (ca. 4.2 billion years ago)
The “First Billion Years of the Geodynamo” is a continuing US NSF-supported project at the University of Rochester that has sought to explore any potential record of Earth’s earliest magnetic field. This has required use of the “single silicate crystal paleointensity” method. Rather than sampling a whole rock, this method relies on the measurement of single silicate crystals. The silicate crystal itself is not of intrinsic magnetic interest. Instead, it is merely a host to even smaller magnetic inclusions, 50 to several hundred nanometers in size, that can retain records of magnetic fields for billions of years. The host can protect the inclusions from geologic events (e.g. mountain building, alteration related to fluid flow) that might otherwise erase their magnetic recordings.   A principal target has been zircons now found in younger (but still Archean-age) sedimentary rocks. However, even the “host” crystals are very small (Figure 3). These measurements have required the development of highly sensitive cryogenic magnetometers to read the magnetic signals.

Figure 3. *Left, single zircon crystal on US dime for scale (look inside the letter “O”). Right, US dime (center) versus EU coins.*

These yield the first evidence, in zircons up to 4.2 billion years old, for a geodynamo. The available Hadean paleointensity values, combined with solar wind estimates suggest strong forcing, with magnetopause standoff distances (Figure 4) of 3 to 4 Earth radii.

The Paleoarchean Earth (ca. 3.45 billion years ago)
The study of single silicate crystals from rocks of South Africa yield evidence for the geomagnetic field, with a strength within 70% of today's intensity. However, the intensity of the solar wind still results in greatly reduced magnetopause standoff distances (approximately 5 Earth radii), equivalent to the value Earth experiences on hour time scales during coronal mass ejection events (and associated magnetic storms). The most obvious sign of this activity today is the occurrence of aurora sightings at relatively low latitude regions. However, this would have been the typical day in the Paleoarchean.

Mesoarchean to Earliest Proterozoic
Paleointensity values from single silicate crystals suggest consistent paleointensity values within 50% of modern field values. During this interval, solar winds abate, and magnetopause values are within ~20% of present day values.

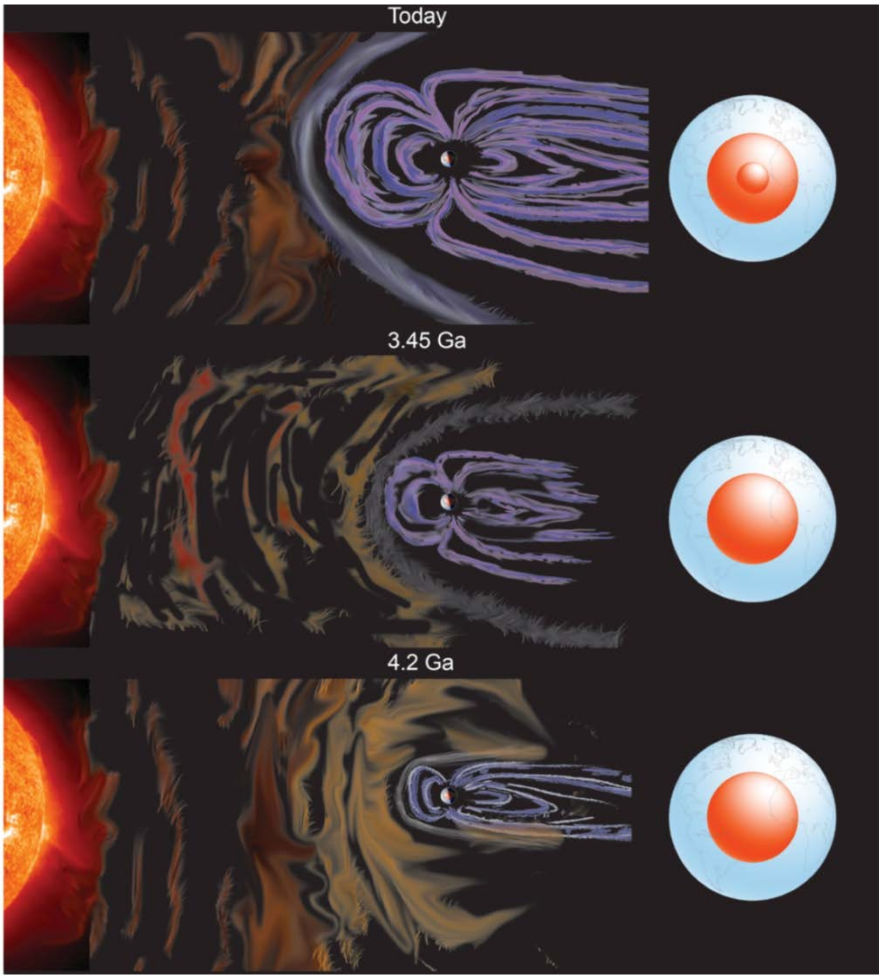

Figure 4. *Cartoon of magnetopause (not to scale) to highlight relative changes with time. Also shown is Earth evolution. Note the lack of a solid inner core for the early Earth. The present day standoff distance is ~10 Earth radii, ~5 Earth radii 3.45 billion years ago and ~3-4 Earth radii for times more than 4 billion years ago. Figure updated from Tarduno (2009) courtesy of Rory Cottrell.*

Habitability and Sustainability

Significant gaps exist, but available data suggest presence of the dynamo from its inception, perhaps shortly after the collision of the proto-Earth and Theia, to today. Chemical precipitation may well have driven convection, and been dominant prior to thermal convection and inner core growth. Even with magnetic shielding the Hadean would have likely experienced volatile loss -including water- because of the extreme solar forcing, but this is also the epoch of water resupply via late arriving asteroids and comets. However, strong forcing continued into the Paleoarchean. The robustness of today's terrestrial water, together with this potential removal mechanism, suggests the water inventory at the end of the period of potential re-deliveries was substantially greater than today. Thus, Earth provides an example where a robust early water supply was of critical importance, and where this hydrosphere was protected by the magnetosphere, setting the stage for the development of life.

Acknowledgements This extended abstract builds on and extends an abstract by the author prepared for a symposium organized by the Magnetics Information Consortium (2017). This work is supported by NSF grants EAR 1656348. Students have been involved in all phases of field and laboratory studies, including Olga LibmanD Roshal who first measured single zircons in our laboratory in 1997 (Figure 5).

***Figure 5**. Olga LibmanDRoshal during a recent visit to the University of Rochester Paleomagnetism Laboratory. In 1997, while an undergraduate working with our group, Olga first measured the magnetizations of zircons. Only the largest zircons registered above background in our 4.2 cm bore 2G 755R SQUID magnetometer during Olga's measurements, but this provided early motivation for efforts that led to the ultrasensitive small bore superconducting quantum interference device (SQUID) magnetometer (shown in background). This magnetometer, constructed by the late Bill Goree, affords the sensitivity for the measurements of zircons. Olga now teaches high school geology and environmental science.*

Reference and Readings

Tarduno, J.A., Cottrell, R.D., Davis, W.J., Nimmo, F., and Bono, R.K., A Hadean to Paleoarchean geodynamo recorded by single zircon crystals, Science, 349, 521-524, 2015.

Tarduno, J.A. et al., Detecting the oldest geodynamo and attendant shielding from the solar wind: Implications for habitability, Physics of Earth and Planetary Interiors, 233, 68D87, 2014. OPEN ACCESS: http://www.sciencedirect.com/science/article/pii/S0031920114001332

Tarduno, J.A., Geodynamo history preserved in single silicate crystals: Origins and long-term mantle control, Elements, 5, 217-222, 2009.

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EDUCATION

Ph.D	Geology	1992,	University La Sapienza (Rome)
M.Sc	Geology	1986	University La Sapienza (Rome)
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CARRER

Jan. 2011	Full Professor, University of Roma TRE, Rome, Italy
Nov. 2011	Associate Professor, University of Roma TRE, Rome, Italy
Nov. 2008	Associate Professor, University of Basilicata, Potenza, Italy
Jul. 2004	Visiting professor at the Institute of Geophysics ETH Zurich
Dec. 1998	Visiting professor at the University of Cergy-Pointoise (France)
Nov. 1992	Ricercatore Universitario (Lecturer), University of Roma TRE, Rome, Italy
Jun. 1992	Ricercatore Universitario (Lecturer), University La Sapienza, Rome, Italy

RESEARCH INTERESTS

Field geology
Structural geology
Paleomagnetism
Tectonics
Geodynamics

PUBLICATIONS AND SERVICES

Author or co-author of more than 100 research papers (most of them in peer-reviewed international Journals) mainly about tectonic evolution and paleomagnetism of Central Mediterranean, Iran, Anatolia Plateau, Gibraltar Arc, Greece, Andes.
Associate Editor of Geological Society American Bulletin since 2013.
Coordinator of the Italian Group of Structural Geology since Jan 2017

SUGGESTED READINGS (WEB RESOURSES OR SCIENTIFIC JOURNAL PAPERS)

Naomi Oreskes - "Plate Tectonics: An Insider's History Of The Modern Theory Of The Earth"
Allan Cox – "Plate Tectonics and Geomagnetic Reversals" W H Freeman & Co. 1973.
https://www.sciencenews.org/article/remnants-earths-original-crust-preserve-time-plate-tectonics
Brown, M., 2006. Duality of thermal regimes is the distinctive characteristic of plate tectonics since the Neoarchean. Geology 34, 961–964.

PLATE TECTONICS: THE SCIENTIFIC REVOLUTION THAT REVEALED HOW OUR PLANET WORKS

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The face of the Earth was very different when it first formed (Fig. 1a), being very far form the wonderful "Blue Planet" that is now routinely pictured by the modern satellites orbiting around it (Fig. 1b). Understanding the processes that have been responsible of the progressive transformation from the inhospitable, "hellish", Early Earth to the present-day shape of our Planet, with its wonderful variety, which includes oceans, continents, atmosphere and life, represents one of the major issues for Earth Sciences researchers. In particular, a main argument of debate is represented by the role of Plate Tectonics in the progressive shaping of our Planet.
Plate Tectonics is a wonderful and useful theory for describing the Earth's behavior during the last few hundred million years, but when Plate Tectonics started in the Earth history is a matter of ongoing debate among geologists. The principal problem is that almost all oceanic crust older than about 200 million years has been destroyed by subduction, hindering an easy comparison with the tectonic processes active today.

***Figure 1**. a) Artist's view of the Hadean Earth from the 1952 cover of Life magazine. b) The Earth from the space (NASA). Most of its present day fascinating shape is related to Plate Tectonic processes.*

Furthermore, some of the main hallmarks of subduction, one of the main features of Plate Tectonics, such as the high-pressure low-temperature metamorphic belts and the preservation of ophiolites, are very poorly represented in orogenic belts that are older than 600 million years. To some geoscientists, this implies that tectonic processes guiding the evolution of Earth were different from those of today. Other geoscientists, however, point out that these features are unlikely to be preserved in ancient orogenic belts or that their absence may be explained by the higher geothermal gradient that must have been present during much of the Precambrian. Although thick sequences of marine sedimentary rocks up to 3.5 billion years old imply that oceanic environments did exist early in Earth's history, virtually none of the oceanic crust that underlay these sediments has been preserved. Despite these disadvantages, there is enough fragmentary evidence to suggest that plate-tectonic processes similar to those of today extend back in

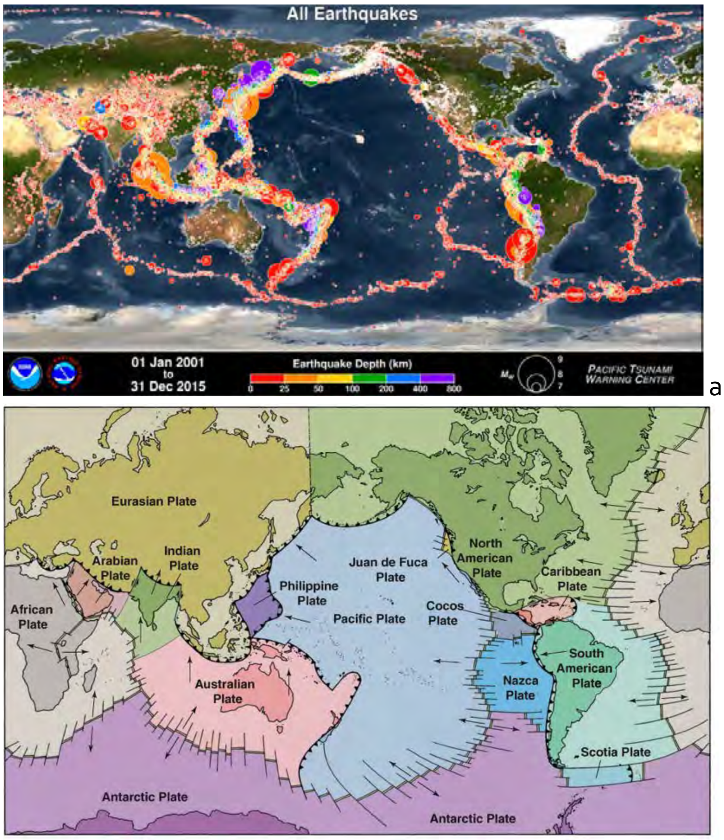
time at least as far as the Paleoproterozoic Era, some 2.5 billion to 1.6 billion years ago.

The discovery of Plate Tectonics has represented a revolution in our understanding of the Planet. However, its full acceptance by the Earth Scientist's community has been an impervious trajectory, which lasted for more than half century starting from the Wegener' hypothesis of Continental Drift. The Continental Drift hypothesis, formulated by Wegener in the early decades of the 20th, was an important step toward the Plate Tectonics as it suggested the possibility that continents masses moved independently on the Earth surface during their evolution. In his hypothesis, Wegener could not consider most of the data that were later taken into account to demonstrate Plate Tectonics. This was particularly important for the two disciplines which mostly contributed to the advent and acceptance of Plate Tectonics: paleomagnetism and seismology, which in the Wegener' age showed a substantial backwardness of technology and available dataset that hindered the possibility to use them to prove continental drifting.

In 1950's paleomagnetism produced remarkable data that allowed confirming the continental mobility hypothesized by Wegener' continental drift theory. The earth scientist community did not take these data in full account until the advent of Plate Tectonics one decade later. At the same time, seismology also gave a lot of evidences of mobility of the Earth lithosphere, especially on the possibility of the existence of subduction zones along the Pacific margins.

These evidences were substantially rejected until geological evidences of coseismic slip of the 1964 Alaska mega-earthquake demonstrated that such plate boundary behaved as was expected for a subduction boundary. Since then, seismology provided a lot of new data which definitely confirmed the Plate Tectonics theory, which is now universally accepted (Fig. 2).

Plate Tectonics is a wonderful theory for explaining the Earth behaviour, and its birth and rooting is a fascinating example of how a very simple scientific hypothesis suddenly became a revolutionary theory, allowing to put together in a comprehensive view scientific data which previously appeared distant and uncorrelated.



a)

b)

Figure 2. a) Global Earthquake distribution (https://www.youtube.com/watch?v=ph7Eczs-nTI); b) tectonic plates (http://www.geogrify.net/).

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EDUCATION
•BSc Honours in Geology, 2(2); University of Bristol, 1968 - 1971.
•MSc 'Sedimentology', (Distinction); University of Reading, 1976 - 1977.
•Postgraduate Certificate in Education; University of Keele, 1977 - 1978.

CAREER
APPOINTMENTS HELD
•Oct 1971 - July 1976 Geologist, De Beers Consolidated Mines Ltd., Kimberley, South Africa.
•Sept 1978 - July 1996 School Teacher, Altrincham Grammar School for Boys,
•Sept 1996 – Aug 2002 Science Education Lecturer: Earth sciences, Keele University
•Sept 2006 – Dec 2015 Professor of Earth Science Education
•Jan 2016 – today Emeritus Professor of Earth Science Education
•Sept 1999 – Dec 2015 Director of the Earth Science Education Unit at Keele University

MEMBERSHIP OF LEARNED BODIES AND PROFESSIONAL ASSOCIATIONS
•Chair of the International Union of Geological Sciences (IUGS) Commission on Geoscience Education
•Adviser (past-Chair and instigator) of the Council of the International Geoscience Education Organisation
•Chair of the Earth Science Education Forum (England and Wales) (ESEF (E & W)).
•Chair of Examiners, Welsh Joint Education Committee (WJEC) Geology 'A' level Examination Committee.
•Fellow of the Geological Society.

OTHER DETAILS OF CAREER
•Leader of the Earthlearningidea team, publishing Earth science activities for the Earthlearningidea website
•Educational Consultant to the 'Building Earth Science Education Resilience' group
RESEARCH INTERESTS
•the development of Earth science teaching.
•monitoring a national programme of Earth science INSET.
•misconceptions in Earth science understanding.
•the international development of Earth science teaching

PUBLICATIONS AND SERVICES
224 publicatons including: 8 authored books, 5 edited collections, 8 chapters in books, 32 publications in peer-reviewed journals, 128 other journal articles and 43 articles in edited collections.

AWARDS AND HONORS
2003 – winner of the Geological Society's 'Distinguished Service Award'
2012 – winner of the Geologists' Association's 'Halstead Medal'

SUGGESTED READINGS (Chapters in books)
•*King, C. (2017) Fostering deep understanding through the use of geoscience investigations, models and thought experiments – the Earth Science Education Unit and Earthlearningidea. In Vasconcelos, C. (ed) Geoscience education: trends and approaches. Dordrecht: Springer.*
•*King, C. (2013) A review of the Earth science content of Science Textbooks in England and Wales. In Myint Swe Khine (ed) Critical Analysis of Science Textbooks: evaluating instructional effectiveness, 123-160. Dordrecht: Springer. ISBN. 978-007-4167-6.*
•*King, C. (2013). Using Research to Promote Action in Earth Science: Professional Development for Teachers. In, Vincent Tong (ed) Geoscience Research and Education. 311-334. Dordrecht: Springer. ISBN 978-94-007-6942-7.*

TEACHING THE STRUCTURE OF THE EARTH AND PLATE TECTONICS

Chris King

Keele University, UK

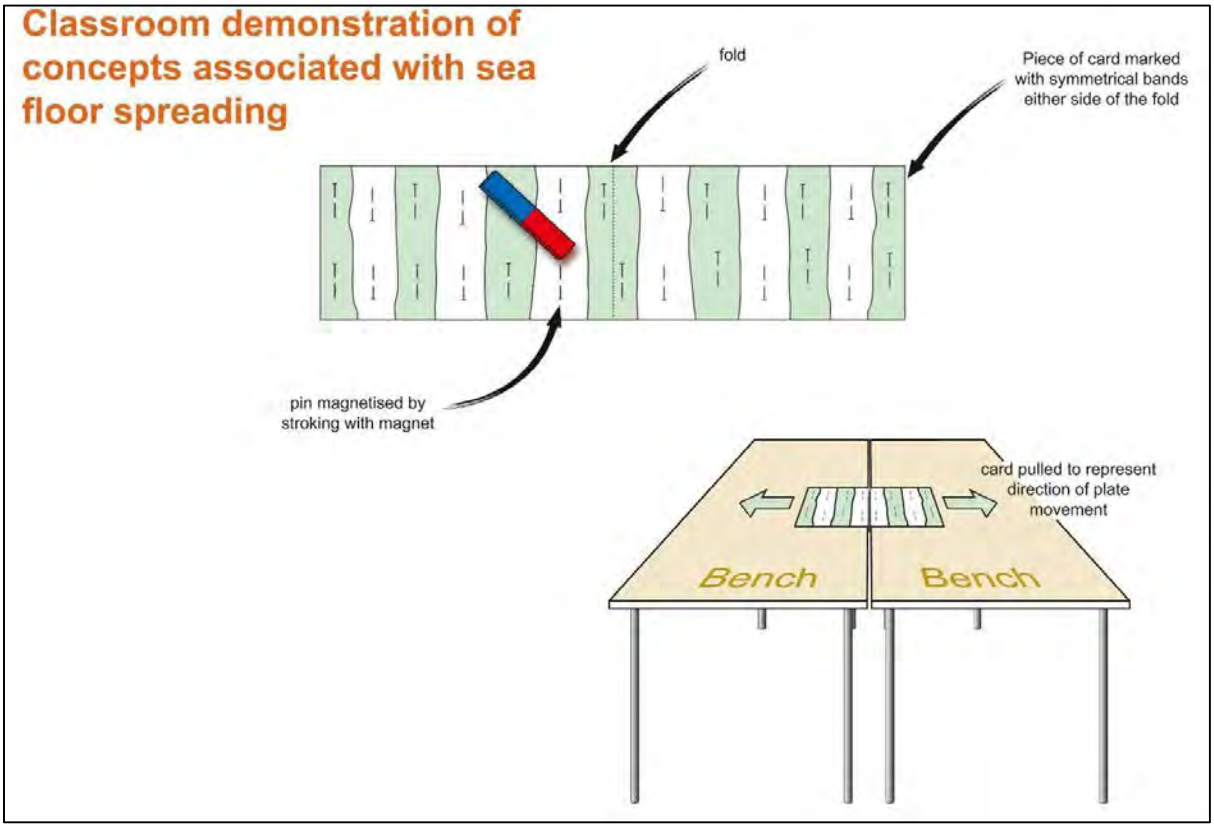
EGU Committee on Education

The structure of the Earth and plate tectonics

'The structure of the Earth and Plate Tectonics' workshop gets to grips with the wide-ranging evidence for the theory that underpins our detailed modern understanding of our dynamic planet – the theory of **Plate Tectonics**. The workshop progresses through a series of hands on interactive activities that are designed to help students develop their understanding. It uses several independent sources of evidence supporting the theory, including using rock and fossil evidence, seismic records, geothermal patterns, geomagnetism, and large-scale topographical features, both above and below sea-level. The workshop provides a reconstruction of plate movements over the past 450 million years which explains the record contained in the rocks beneath our feet - recording amazing plate journeys across the face of our planet.

The workshop and its activities provide the following outcomes:

- an introduction to plate tectonics;
- distinction between the 'facts' of plate tectonics and the evidence used to support plate tectonic theory;
- a survey of some of the evidence supporting plate tectonic theory;
- an introduction to the evidence for the structure of the Earth and the links between the structure of the outer Earth and plate tectonics;
- explanation of some of the hazards caused by plate tectonic processes;
- methods of teaching the abstract concepts of plate tectonics, using a wide range of teaching approaches, including practical, hands on, interactive and electronic simulations;
- approaches to activities designed to develop the thinking and investigational skills of students.



Jérémy CAMPONOVO
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International High School, Valbonne,
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I hold the 'agrégation', the highest teaching diploma in France since 2006 in physics and chemistry, and a PhD in organic chemistry since 2010. I was a student at the 'Ecole Normale Supérieure' and hold an engineering degree of the 'Ecole Nationale Superieure de Chimie de Paris'.
I was a teacher in Bordeaux I university between 2007 and 2010 in licence degree, master degree and for graduate students who are preparing the competitive examination to become a teacher.
I teach now physics, chemistry, computer science, robotics and aeronautics for students from 11 to 20 year old in middle school, high school and CPGE (preparatory class for entrance to french Grandes Ecoles). I also animate the astronomy club of my school in link with the Observatoire de la Côte d'Azur laboratory (OCA). I am involved in the preparation of the french team for IESO for a few years and I participated in the organisation of the IESO 2017 in France.
I am very interested in cross-curriculum approach in education, that is why I participate in international meetings (european SERA project), in producing resources for the educational part of the NASA's Mars Insight project (https://insight.oca.eu) and in the Edumed-Observatory project (www.edumed-obs.fr) funded by the Université Côte d'Azur (UCA).

Diane Carrer
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Académie de Nice France
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I hold the « agregation », the highest teaching diploma in France in Biology and Geology , and I teach since 5 years in high-schools. After an engineering diploma in agronomy, soil science and environment science, I used to work for a couple of years in an industrial company called Vinci. After that experience, I've quitted my engineering job to become a teacher … and I am very happy with that professional choice.
Since 5 years , I teach students from 6 grades to 12th grade, and I am also in charge of practical courses at university (petrology, volcanology and metamorphism).
I am involved in several educational programs, in Geosciences, such Seismology at school, the study of Mermaids (Mobile EarthQuake Marine Recording devices), InSight and SEIS mission on Mars, EDUMED programs (hydrology, seismology, geodesy and natural hazards).
In that context, I've participated to the EGU workshop in 2016 to present some pratical activities about astronomy and InSight mission to the red planet.
I am also involved in the preparation of french students for the International Earth Science Olympiads.
Last year, I was also part of the organization team of IESO in Sophia Antipolis, France, which was a great experience.

CRATER IMPACT LAB

Diane Carrer and Jérémy Camponovo
International High School Valbonne, France

In this session, we will present simple hands on activities on impact craters. The investigations will use written documents, practical experiments and numeric exploitation, including data recording, curves modelling and doing simulations.
We will show how to investigate which factor is linked to the diameter of an impact crater (volume of the impactor, mass of the impactor, density of the impactor and so on) using low velocity marbles, flour and coffee powder. Adding a webcam to the system allows to do a modelling to be able to predict the size of a crater knowing the impactor energy or to calculate the energy of the impactor knowing the size of the crater.

We will present how to use photographs of Mars or Moon surface to understand the notion of probability of impact events toward the size of the impactor. Then, we will show how to measure the size (diameter and depth) of an impact crater on photographs using a simple software.

We will finally explain how to use handmade piezo electric sensors or 3-axis accelerometers to record data (simulating seismometers) and to calibrate the curves using the known energy of the impactors.

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EDUCATION

1996 Ph.D. (Geochemistry) California Institute of Technology, Pasadena, CA
1991 M.S. (Geochemistry) California Institute of Technology, Pasadena, CA
1989 A.B. (Geological Sciences and Chemistry) Harvard College, Cambridge, MA

CAREER

2016 – present Co-Director, ASU PlanetWorks Initiative
2015 – present Director, ASU Center for Education Through Exploration
2004 – present Associate Professor, Professor, and President's Professor (School of Earth & Space Exploration and School of Molecular Sciences, Arizona State University, Tempe, AZ, USA)
1996 – 2004 Assistant Professor, Associate Professor (Dept. of Earth & Environmental Sciences and Dept. of Chemistry University of Rochester, Rochester, NY, USA)

RESEARCH INTERESTS

I am a scientist and educator interested in Earth's past and future as an inhabited world, and the prospects for life beyond. My research group develops novel geochemical methods to study topics ranging from the chemical evolution of the atmosphere and oceans to human disease. I co-direct ASU's PlanetWorks Initiative, which aims to advance research, conversation, and education around the looming challenges of Earth system management. In education, I lead a team developing Earth and space science digital learning experiences that advance reasoning and problem solving in science education, at internet scale.

PUBLICATIONS AND SERVICES

A good primer for my presentation (includes public access URL):
The Great Oxidation Event: Evolving understandings of how oxygenic life on Earth began. By R. Blaustein. *BioScience*, Volume 66, Issue 3, 1 March 2016, Pages 189–195.
https://doi.org/10.1093/biosci/biv193
Three relevant peer-reviewed papers:

- A. D. Anbar, C. B. Till, and M. A. Hannah (2016). Bridging the planetary divide. Nature **539**: 25-27.
- A. D. Anbar (2008). Elements and evolution. Science **322**: 1481-1483.
- A. D. Anbar, Y. Duan, T. W. Lyons, G. L. Arnold, B. Kendall, R. A. Creaser, A. J. Kaufman, G. Gordon, C. Scott, J. Garvin and R. Buick (2007). A whiff of oxygen before the Great Oxidation Event? Science **317**: 1903-1906.

My views on education (includes public access URL):
A.D. Anbar. Is Pluto a Planet? Who Cares! Op-ed in *Slate*, 2015
http://www.slate.com/articles/technology/future_tense/2015/07/new_horizons_what_pluto_tells_us_about_scientific_literacy.html
Some digital education resources from my center: http://infiniscope.org, http://inspark.education, http://vft.asu.edu

AWARDS AND HONORS

Named one of 10 "teaching innovators", *Chronicle of Higher Education*, 2017, Endowed Biogeochemistry Lecture at Goldschmidt 2017, Geochemical Society, 2017, Fellow, Geochemical Society, elected 2015, President, President-Elect, Biogeosciences Section, American Geophysical Union, 2015 – 2017, Howard Hughes Medical Institute Professor, 2014, Fellow, Geological Society of America, elected 2003, Young Scientist Award (Donath Medal), Geological Society of America, 2002.

THE GREAT OXIDATION EVENT, 2.3 BILLION YEARS AGO

Ariel Anbar
Arizona State University, Tempe, Arizona, USA

At its surface, Earth is an oxygenated world. In the atmosphere, molecular oxygen (O_2) is the second-most abundant gas. Throughout most of the oceans, seawater is saturated with O_2 or nearly so – it holds as much of this gas in dissolved form as it can. This high abundance of O_2 makes animal life possible. Where O_2 is scarce, only microbes can survive. No wonder, then, that scientists planning the search for life on other worlds hope to find telltale signs of this molecule in alien atmospheres.

Yet, O_2 was not always so abundant. The timing and tempo of Earth's O_2 history is an area of active study (Fig. 1). We now know that for roughly the first half of Earth's history, O_2 was vanishingly rare in the atmosphere and oceans. Around 2.3 billion years ago – about halfway through Earth's history – O_2 in the atmosphere rose above 10^{-6} atm, beginning an ascent to the high levels of today.

This *Great Oxidation Event* ("GOE") transformed Earth's surface environment, apparently irreversibly. It marks one of the most profound transitions in Earth's evolution as a living world. Yet, its cause remains a mystery! Solving it is a key challenge for Earth systems scientists. It is also a challenge for astrobiologists: their ability to use O_2 as a signature of life planets beyond our Solar System hinges on a better understanding of how it arose on Earth.

It is, of course, tempting to explain the onset of the GOE as the immediate consequence of the evolution of O_2-producing ("oxygenic") photosynthesis. Atmospheric O_2 today derives from this process, and so this evolutionary innovation was clearly necessary for the rise of O_2. However, mounting evidence suggests that photosynthesis was producing O_2 as early as 3.5 billion years ago. Therefore, geoscientists are increasingly driven to the idea that something prevented this gas from accumulating in the atmosphere and oceans for a billion years or more before the GOE, even though it was already being produced. It appears that biological O_2 production, while necessary, was not sufficient on its own to explain the rise of O_2.

The possibility of early production of O_2 begins with evidence of microbial 'mats' living in shallow waters of ancient seashores — preserved today as fossilized stromatolites. Paleontological examination of these fossils indicates that they were inhabited by photosynthetic microbes, potentially including O_2-producing cyanobacteria.

This view is buttressed by multiple lines of geochemical evidence in sedimentary rocks deposited before the GOE that can be interpreted as representing transient "whiffs" of O_2. For example, in the 2.5-billion-year-old Mt. McRae Shale in the Hamersley Basin of Western Australia, a host of environmental "redox proxies" point to increased environmental oxidation (Fig. 2). These proxies

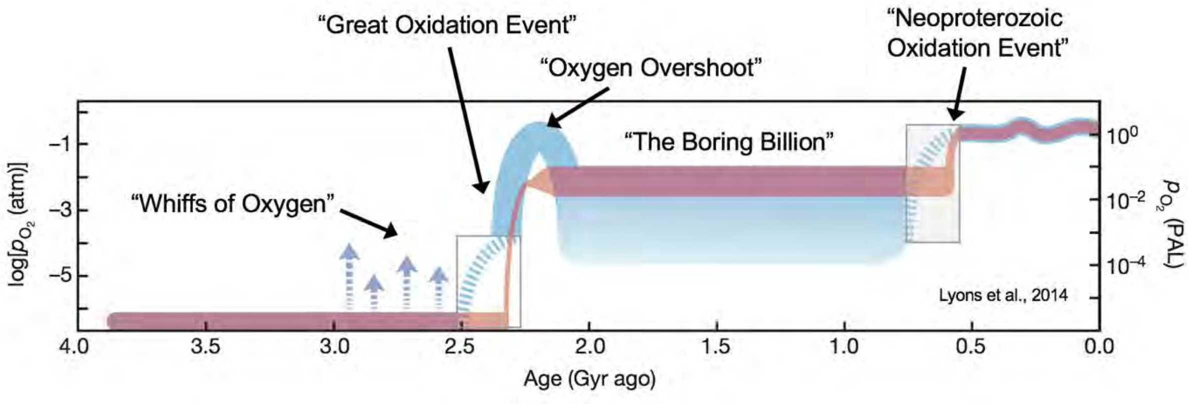

Figure 1. *Adapted from Lyons et al. (2014). The red curve shows the classical view of atmospheric evolution. The blue curve shows the more complex view emerging from recent studies. Right axis, p_{O2} relative to the present atmospheric level (PAL); left axis, log p_{O2}.*

include enhanced abundances of molybdenum (Mo) and rhenium (Re), changes in the chemical forms of iron (Fe), and in the isotope abundances of Mo, uranium (U), nitrogen (N), sulfur (S), selenium (Se), osmium (Os), and thallium (Tl) in these well-preserved sediments. At the same time, several other lines of geochemical evidence – particularly the abundance of Fe-rich marine sedimentary rocks and unusual S isotope signatures derived from the atmosphere – tell us that, despite these possible fingerprints of O_2 production, the oceans and atmosphere did not accumulate large amounts of O_2 until after the GOE.

What might have prevented the accumulation of O_2 in Earth's atmosphere and oceans for nearly a billion years despite the possibility of widespread biological production? The answer may lie in the interactions between Earth's surface and interior, where O_2 is vanishingly rare. Rocks derived from the mantle, such as basalts, consume O_2 when they weather. Oxygen also reacts with H_2 and other gases released from volcanoes, hydrothermal vents, and mineral reactions. Because the atmosphere is thin compared with the planet's internal bulk, Earth's interior's capacity to consume O_2 is effectively infinite compared to O_2 produced at the surface. Therefore, even small changes in the rates at which these rocks and gases consume O_2 could have a big impact on the surface environment. Those changes might arise from alterations in the compositions of materials derived from the mantle, or in the rates at which they are brought to the surface or are dragged back down by the subduction of tectonic plates.

Such alterations surely occurred over time. As Earth cooled after its formation, mantle convection changed and slowed. The abundance of Fe and magnesium in magmas derived from the mantle decreased. The modern tectonic processes that recycle crust into the mantle kicked in. The crust became richer in silicon dioxide, and more buoyant. The distribution of heat and elements in the mantle were altered as surface minerals were mixed in, and as iron–nickel alloy was steadily lost to Earth's growing core.

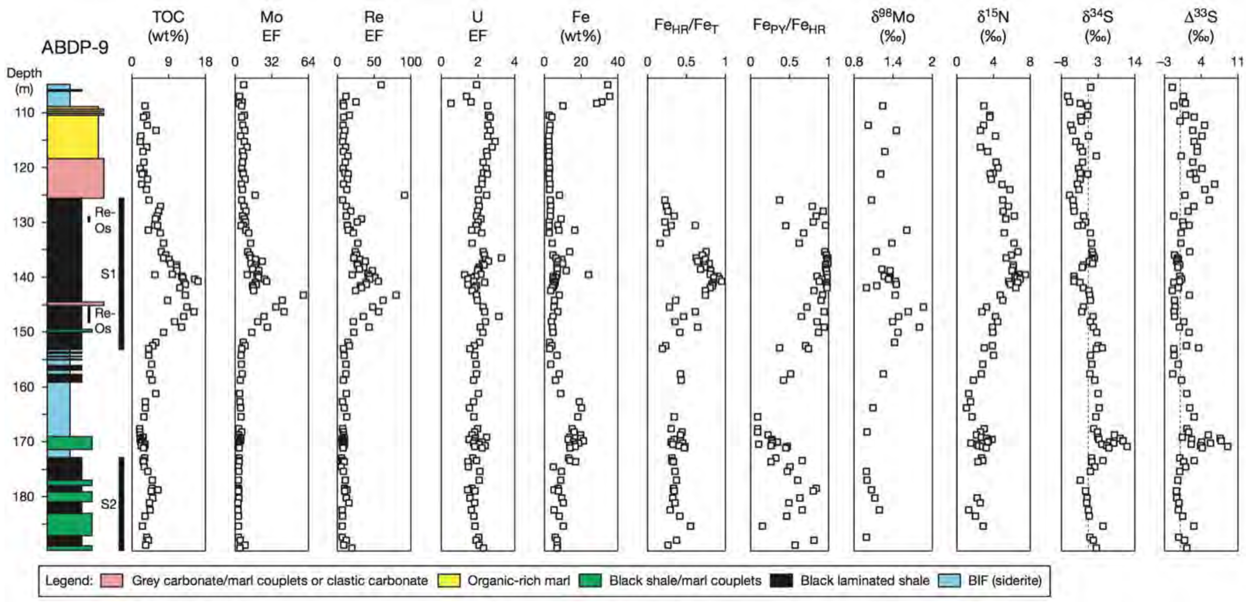

Figure 2. *Adapted from Lowenstein et al. (2014). Geochemical profiles from the Mt. McRae Shale interpreted as a "whiff" of O_2 2.5 billion years ago. Elevated TOC (total organic carbon), FeHR/FeT (ratios of biogeochemically highly reactive Fe to total Fe), and FePY/FeHR (ratios of pyrite Fe to highly reactive Fe), and S isotopes, point to locally H_2S-rich conditions and hence an appreciable supply of S, presumably as sulfate derived from oxidative weathering, to the basin during the deposition of interval S1. Enrichments of Mo and Re in this interval indicate the presence of these redox-sensitive elements in contemporaneous seawater, while the absence of a corresponding U enrichment suggests that O_2 levels were very low. The shifts in δ^{98}Mo and δ^{15}N are both consistent with transient oxidative weathering and a secular increase in ocean oxygenation. Not shown here are consistent U, Se, Os, and Tl isotope variations. The occurrence of nonzero Δ^{33}S throughout the interval indicates that despite the O_2 production suggested by these proxies, p_{O2} remained $<10^{-5}$ PAL throughout.*

This cascade of changes probably affected O_2 at the surface. By the time of the GOE, the rate of O_2 consumption by reaction with rocks and gases originating in Earth's interior may have slowed enough that O_2 produced by photosynthesis could accumulate in the atmosphere. However, none of these changes is well-quantified. For instance, whether the upper mantle's capacity to consume O_2 evolved or not is still debated. For 20 years, researchers thought that it did not. But recent measurements of vanadium and scandium in ancient rocks derived from the mantle suggest that its O_2 consumption capacity might have fallen in the 1.5-billion-year run-up to the GOE. Changes in the composition of the continental crust also suggest a decrease in O_2 consumption by rock-weathering processes around the same time.

Ironically, unravelling the mystery of Earth's surface O_2 evolution requires that we understand the evolution of Earth's interior! Ultimately, what is needed is no less than a quantitative theoretical model of the physics and chemistry of planetary cooling and its consequences for surface–interior interactions over time. Superficially, at least the core of such a theory is straightforward. In reality, to develop such a theory is an immense generational "grand challenge" requiring fundamental advances and vigorous collaboration across subdisciplines that rarely interact. The hurdles are both scientific and sociological.

The author thanks Prof. Christy Till for contributions related to solid Earth evolution.

Key references (and references therein):

Anbar, A. D., Till, C. B., & Hannah, M. A. (2016). Bridge the planetary divide. *Nature News*, *539*, 25.

Kendall, B., Creaser, R. A., Reinhard, C. T., Lyons, T. W., & Anbar, A. D. (2015). Transient episodes of mild environmental oxygenation and oxidative continental weathering during the late Archean. *Science Advances*, *1*, e1500777.

Lowenstein, T. K., Kendall, B., & Anbar, A. D. (2013). The geologic history of seawater. In *Treatise on Geochemistry: Second Edition*. Elsevier Inc.

Lyons, T. W., Reinhard, C. T., & Planavsky, N. J. (2014). The rise of oxygen in Earth's early ocean and atmosphere. *Nature*, *506*, 307-315.

Stüeken, E. E., Buick, R., & Anbar, A. D. (2015). Selenium isotopes support free O_2 in the latest Archean. *Geology*, *43*, 259-262.

ISABELLE ANSORGE

Professor – Head of Department the
Department of Oceanography, University of Cape Town, RSA
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Isabelle teaching SEAmester students on the SA Agulhas II

Prof Isabelle Ansorge - is the Head of the Oceanography Department at the University of Cape Town in South Africa. Isabelle's research interests focus on the impact changes in the Antarctic Circumpolar Current in the Southern Ocean have on Subantarctic Islands and the impact on their ecosystem functioning. She has been involved as the South African co-ordinator for the highly prestigious and privately funded Antarctic Circumpolar Expedition (ACE). In addition, Isabelle is responsible for the hands-on sea going training of all postgraduate students at the University of Cape Town and heads up the highly successful "SEAmester" Class Afloat programme, which enables students from all South African universities and technikons to gain experience working at sea. Isabelle is also the Principle Investigator of the SAMOC-SA (South Atlantic Meridional Overturning Circulation) programme and has a large cohort of postgraduate students and postdocs working on the ocean variability around South Africa. Finally, Isabelle is the Vice President of the International Association for Physical Oceanography (IAPSO) and an Executive Bureau member on the International Union of Geodesy and Geophysics (IUGG).

EDUCATION

1997-2000
University of Cape Town, South Africa. : PhD. in Physical Oceanography.
Dissertation: The hydrography and dynamics of the general ocean environment of the Prince Edward Islands (Southern Ocean).
1993-1996
University of Cape Town, South Africa. : MSc. in Physical Oceanography.
Dissertation: The structure and transport of the Agulhas Return Current.
1989-1992
University of Plymouth, United Kingdom. : BSc. Honours (2.1) in Ocean Science

CAREER

January 2016	:	Associate Professor and Head of Oceanography, UCT
January 2010	:	Senior Lecturer – Oceanography Department, UCT
January 2006 - 2009	:	Lecturer – Oceanography Department, UCT

PUBLICATIONS AND SERVICES

Ansorge IJ, Brundrit G, Brundrit J, Dorrington R, Fawcett S, Gammon D, **[et al.]** (2016). SEAmester –South Africa's first class afloat. S Afr J Sci.,112(9/10): Art. #a0171, 4 pages.

Braby L, Backeberg BC, Ansorge I, Roberts MJ, Krug M and Reason CJC (2016). Observed eddy dissipation in the Agulhas Current, Geophys. Res. Lett., 43:8143–8150, doi:10.1002/2016GL069480.

Hutchinson K, Swart S, Meijers A., Ansorge I and Speich S (2016).Decadal-scale thermohaline variability in the Atlantic sector of the Southern Ocean, J. Geophys. Res. Oceans, 121:3171-3189, doi:10.1002/2015JC011491.

Olsen et al., 1016 - Cytotoxic activity of marine sponge extracts from the sub-Antarctic Islands and the Southern Ocean. S.Afr. J.sci, vol. 112, n.11.12.

Massie P, McIntyre T, Ryan PG, Bester MN Bornemann H and Ansorge IJ (2016). The role of eddies in the diving behaviour of female southern elephant seals. Polar Biology, vol. 39, pp. 297-307.

SHAPING THE EARTH – FROM PANGAEA…AND POSSIBLY BACK AGAIN!

Isabelle Ansorge
University of Cape Town, South Africa

How did we come to the shape of today's Earth? And how will its shape change over the next 200 million years? Will North America cross the equator? Will Antarctica move away from the poles and green-up? Will India become Africa's neighbour once again? These are just a few of the many questions asked by today's science students.

The Earth is thought to have been formed about 4.6 billion years ago by collisions in the giant cloud of material that also formed the Sun. At first, super-heated gases were able to escape into outer space, but as the Earth cooled, they were held by gravity to form the early atmosphere. Clouds began to develop as water vapour collected in the air forming condensation and overtime the oceans were formed. Most scientists agree that the atmosphere and the oceans accumulated gradually over millions of years with the continual 'degassing' of the Earth's interior. The oceans formed because of the escape of water vapor and other gases from the Earth's molten rocks and in cooling formed rain. As the water drained into the great hollows in the Earth's surface, the primeval ocean came into existence. The forces of gravity prevented the water from leaving the planet.

Professor Alfred Wegner, a German meteorologist in 1912, first hypothesised that continents and oceans began to form over 300 million years ago. He proposed that continents had formed as a single "super continent" from the volcanic rocks. The single land mass called Pangaea, which, over 200 million years broke to form two giant continents, Gondwana and Laurasia (Figure 1). Gondwana comprised of what is now Africa, South America, Australia, Antarctica and India. The Indian sub-continent lay off the east coast of Africa, before breaking off and in its move northwards collided with Asia forming the Himalayas. During this time there was only one ocean called Tethys.

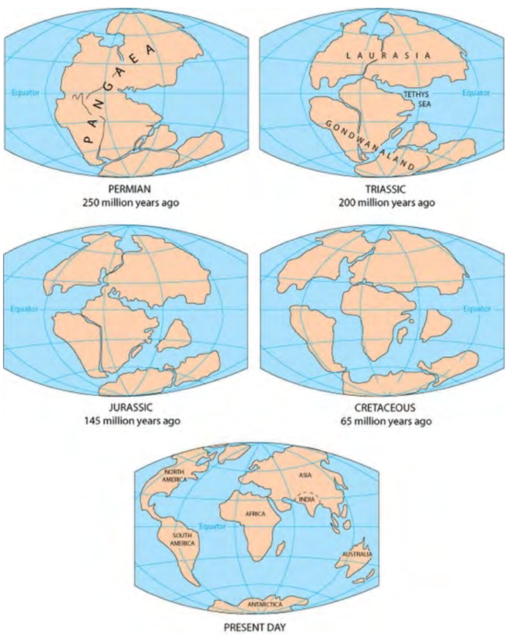

Figure 1 *– Schematic showing the gradual movement of continents form the time of Pangaea to current day.*

As the centuries rolled on the world started to gradually look like what it is today.

But how do we know this?

In the late 1960s, geologists and ocean surveyors began to map ocean basins in an effort to better understand plate tectonics and how the continents had evolved over the millions of years. Their theory is undoubtedly the most important geological hypothesis ever developed and explains the earthquakes, volcanoes, the formation of mountains, and other geophysical phenomena to interactions of the rigid plates forming the earth's crust. The interior of Earth is divided into crust,

mantle and core. The earth's surface layer, or lithosphere, consists of seven large and eighteen smaller plates that move and interact in various ways. They converge, diverge and slip past one another in constant slow motion creating the earth's seismic and volcanic activities – a process known as Continental drift.

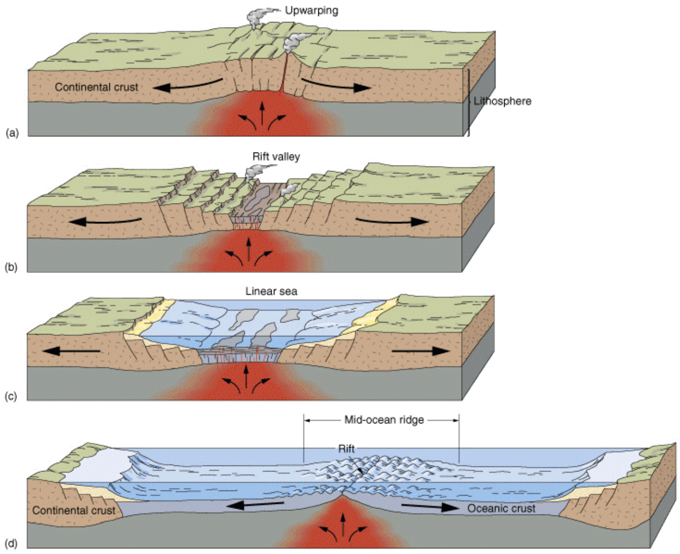

Figure 2*: A Schematic on how the ocean basins have formed over the millions of years.*

Moving Oceans

There are many observations either from space, magnetic surveys of sea floor or seismography that have produced evidence that there are cracks in the sea floor where magma wells up to the surface to form ridges. While in reverse - destruction of the sea floor occurs by plates being driven downwards into the interior of the earth – areas known as subduction zones. The rate of construction or destruction of the tectonic plates is not uniform and provides an explanation on how our ocean basins have formed, how they are growing and in some cases at what rate they are diminishing. For instance, the Pacific Ocean is shrinking at about the same rate as the Atlantic Ocean is expanding. Modelled projections of the earth in 225 million years provide a very interesting pattern of continents

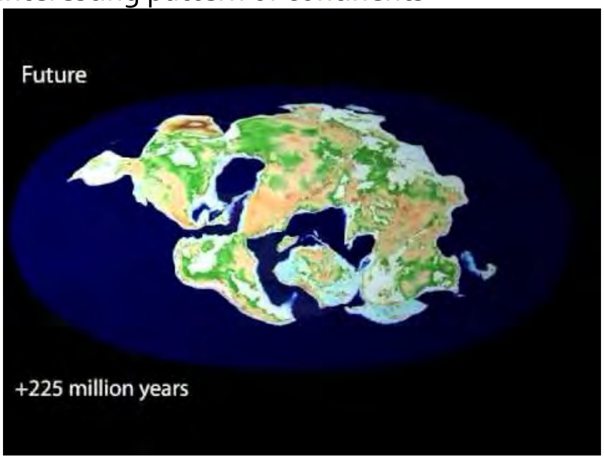

Figure 3*: The world in 225 million years time!*

This lecture will provide an overview of how we moved from the big bang to today's science which has shown that the surface of the Earth and especially the ocean basins are in a constant state of change. Scientists are able to observe and measure mountains rising and eroding, oceans expanding and shrinking, volcanoes erupting and earthquakes striking and by mapping these changes we are able to highlight where we have come from…and where we are going!

Dr David Bond
School of Environmental Sciences
University of Hull, United Kingdom Postgraduate
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www.hull.ac.uk/Faculties/staff-profiles/David-Bond.aspx
tw:@davidpgbond

EDUCATION

2015: PCAP (Postgraduate Certificate in Academic Practice), Univ. of Hull, UK
2004: PhD in Geology, School of Earth Sciences, University of Leeds, UK
2000: BSc in Environmental Geology, School of Earth Sciences, University of Leeds, UK

CAREER

2013 - now	Senior Lecturer (since 2015) in Geology, University of Hull
2013 - now	NERC Advanced Research Fellow (until 2018), University of Hull
2012-13	Marie Curie Intra-European Fellow, Norwegian Polar Institute, Tromsø
2010-12	Research Skills Trainer, University of Leeds
2006-10	PDRA & Teaching Fellow, University of Leeds
2004-10	Temporary Lecturer, University of Leeds

RESEARCH INTERESTS

David's research looks at the record of environmental change during Earth's greatest mass extinctions. His NERC-funded research investigates three crises that occurred between the Middle Permian and end Triassic - an interval of extremes of climate, extinction and evolution that saw Earth's greatest crisis at the Permian-Triassic boundary. His recent work has been in the "Boreal Realm" of northern high latitudes, one of the least understood regions in mass extinction scenarios.

His focus is the role of major volcanism (large igneous province eruptions) in environmental crises, and the effects of warming, oceanic oxygen depletion and acidification on marine ecosystems. David is a field geologist who has worked in 30 countries and has published on extinctions from 445 million years ago to the present. Despite his thirst for travel, David has recently begun "recreating" past extinction scenarios (of e.g. acid oceans, elevated CO_2 atmospheres, low oxygenation) in aquaria in Hull in order to better predict the fate of marine ecosystems not only in deep time, but also in our near future. Remember - if it has happened before, it can happen again!

PUBLICATIONS AND SERVICES

Bond, D.P.G., & Grasby, S.E., 2016. On the Causes of Mass Extinctions, *Palaeogeog., Palaeoclim., Palaeoecol.*, 478, p. 3-29. https://doi.org/10.1016/j.palaeo.2016.11.005 (open review of extinctions).

Council Member, Palaeontological Association --- Review Editor, Frontiers in Paleontology --- Guest Editor, Palaeogeography, Palaeoclimatology, Palaeoecology (Mass Extinction Causality, 2017) --- Guest Editor, Geological Society of America Special Publications --- Fellow, Higher Education Academy --- Fellow, Geological Society of London --- Member, Geological Society of America --- Member, European Geosciences Union.

HOW VOLCANIC ERUPTIONS CAUSED EARTH'S GREATEST MASS EXTINCTION AND WHAT THAT TELLS US ABOUT THE FUTURE

David P.G. Bond
University of Hull, United Kingdom

At the end of the Permian, 252 million years (Myr) ago, Earth suffered its greatest ever crisis during which around 90% of living species were wiped out. Almost every group was affected, on land, and in the oceans, and it is the only mass extinction of insects. This truly was "the day the Earth nearly died" (although it lasted significantly longer than a day!). This was an event so catastrophic that it wiped the evolutionary slate clean, ultimately paving the way for the rise of the dinosaurs (and then, of course, humans). But what could possibly have caused such a disaster?

"Mass extinction" in the minds of most members of the public is encapsulated by the demise of the (non-avian) dinosaurs at the end of the Cretaceous period, around 66 million years ago. That event is famously linked to a giant meteorite impact in what is now Mexico. There has been a tendency for the public, and many scientists, to link all mass extinctions to such a devastating (and evocative) cause, and indeed meteorite impact features in several iterations of the end-Permian scenario. However, unlike the end-Cretaceous extinction, the end-Permian world features no convincing meteorite impact crater, nor any indirect evidence for death-from-outer-space. Instead, two decades of research have brought scientists to a consensus that points the finger of blame at the unimaginably huge volcanic eruptions of a "large igneous province" (LIP): the Siberian Traps (from the Swedish for "ladder", reflecting how such volcanic rocks often appear in the field). The Siberian eruptions were unlike anything in human history - they were not Pinatubo-esque, nor even remotely like those at Laki, that dealt widespread misery to Iceland in 1783-4 and brought about the French revolution. No, the Siberian Traps lavas have a volume of 6 million km3, enough to bury the whole of Austria under 71.5 km of lava. That's a lot of lava, and it had a catastrophic effect on the world's environments and ecosystems.

Despite controversy over the timing of losses, radio-isotopic dating indicates that extensive damage was done to both terrestrial and marine ecosystems in a very brief interval around the end of the period. The focus now is on understanding the role of the proposed kill mechanisms (Figure 1), including (in no particular order): global warming, ocean anoxia (deoxygenation) and acidification, volcanic winter, hypercapnia (CO2 poisoning), aridity on land, increased sediment flux to the oceans, ozone destruction and resultant harmful ultraviolet-B radiation, acid rain, atmospheric oxygen depletion, and poisoning by toxic trace metals. Each has probable origins in Siberian Traps volcanism, in particular the vast volumes of gases (e.g. CO2) that must have been released. The latest work is beginning to reveal the likeliest culprits: extreme global warming and its knock-on effects, perhaps coupled with an acidification crisis in the oceans.

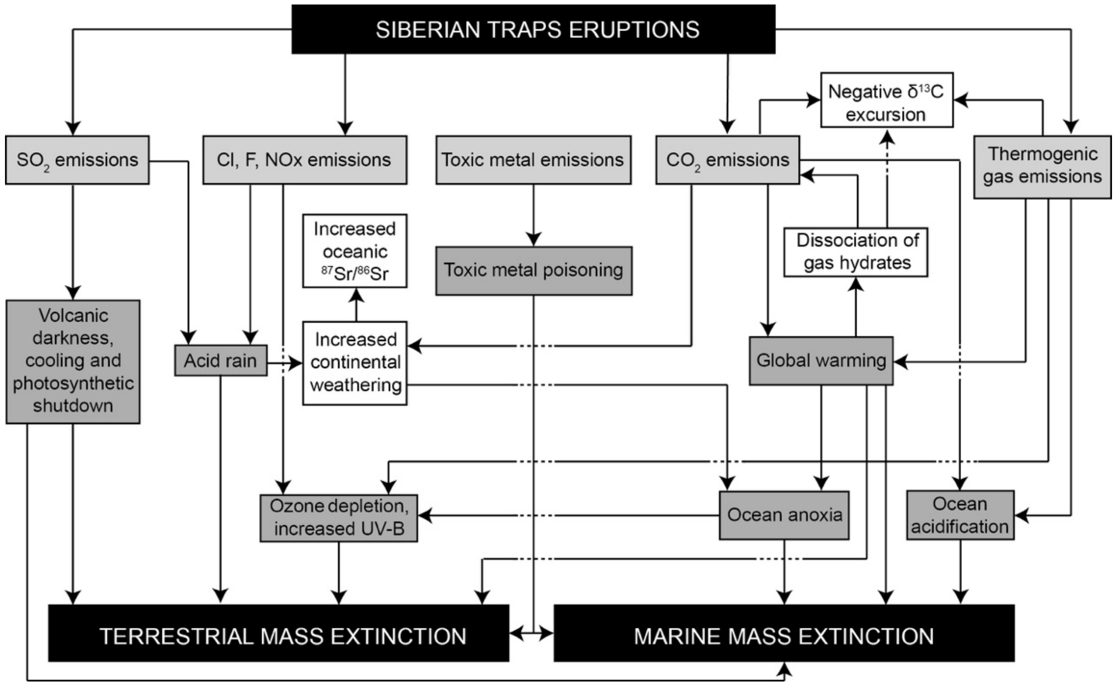

Figure 1: Flow chart of extinction drivers linked to Siberian Traps eruptions.

The recovery of life after this crisis took a long time, perhaps 10 Myr. Normally, life could recover faster, but so many species had been lost that whole key habitats were destroyed, including coral reefs and forests. The initial causes of the catastrophe continued to devastate Early Triassic environments and slowed the biotic recovery. Thus, as tropical oceans continued to warm to an extraordinary 45° C (a very hot bath), life really was pushed to the limits just in order to survive (Figure 2).

Figure 2: One of the survivors, Lystrosaurus, looking out over a barren Antarctica. From a painting by the American artist, William Stout (1981).

Mass extinctions are of great interest to biologists as times that mark major changes in floras and faunas. The end-Permian mass extinction has been said to have 'punctuated' or 'reset' the history of life. Although the catastrophe wiped out 90% or more of Palaeozoic species on land and in the oceans, it provided opportunities for the survivors to radiate and ultimately give rise to the 'modern' fauna and flora. Extinction and evolution go hand-in-hand. Around 20 million years after taking its worst hit, Earth's climates returned to a more "normal" state, the planet greened-up once more, and the first dinosaurs appeared, paving the way for the next great chapter in the history of life.

POSTSCRIPT: what can we learn from past disasters and why are they relevant today?

The "Anthropocene" (as a concept, and possibly soon as a geological time interval) has brought attention to the fact that Earth is once again facing some of the stresses implicated in its past crises (Figure 3). Put simply: if it has happened before, it could happen again. Despite the research summarized above, and some pretty good models of Earth's near future, we still have limited understanding of how global warming, acidification, and anoxia actually affect ecosystems. We do not know why or how these stresses sometimes lead to profound collapses in Earth's ability to support life, whilst there have been times when the same stresses had apparently little effect on the biosphere. Advances in experimental biology are beginning to provide the missing link in our knowledge of extinction scenarios, as well as inform our understanding of Earth's near future. Unfortunately, some of the data makes for scary reading, as fears grow that Earth might be entering its next great mass extinction. Although we do not expect another large igneous province eruption any time soon, there are remarkable parallels between the processes by which the Siberian Traps did so much damage and anthropogenic effects on the modern planet. There are, however, mitigating factors that provide some cause for optimism: Pangaea (or lack of). Since its break-up, there has only been once major biocrises, and that was a unique event in that (for once) it did coincide with a major meteorite impact.

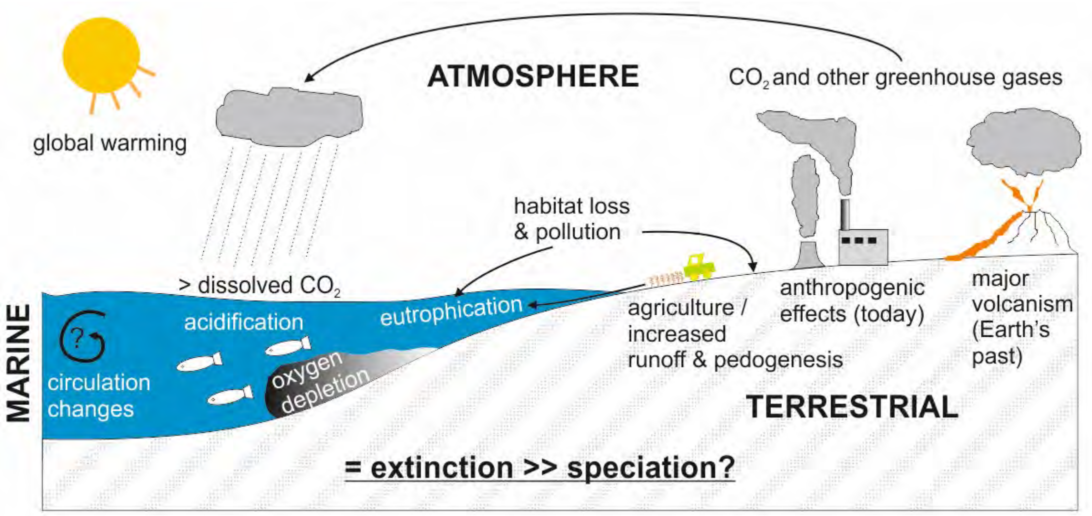

Figure 3: Past and future threats to the biosphere have different origins but potentially similar effects. There is growing concern that the rate of modern extinctions might begin to greatly exceed that of speciations, with the result that Earth will suffer another mass extinction to characterise the "Anthropocene".

FURTHER READING

Bond, D.P.G., and Grasby, S.E. (2016). On the causes of mass extinctions. Palaeogeography, Palaeoclimatology, Palaeoecology, dx.doi.org/10.1016/j.palaeo.2016.11.005

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EDUCATION
PhD 1983 (astronomy, chemistry)

CAREER
1985-1990, Assistant Professor (Geochemistry), University of Vienna
1991-2008, Associate Professor (Geo- and Cosmochemistry), University of Vienna
2008 ff: Full Professor (Planetary Geology and Impact Research), University of Vienna
2009 ff: Director General, Natural History Museum Vienna, Austria
Various visiting appointments: Lunar and Planetary Institute/NASA Houston; Carnegie Institutrion Washington, USA; Dartmouth College, USA; University of the Witwatersrand, Johannesburg, South Africa; Open University, Milton Keynes, UK.

RESEARCH INTERESTS

Cosmochemistry, meteorite impacts, meteorites, planetary geology, isotope geochemistry

PUBLICATIONS AND SERVICES

Koeberl, C., and MacLeod, K., Eds. (2002) Catastrophic Events and Mass Extinctions: Impacts and Beyond. *Geological Society of America, Special Paper* **356**, 746 pp (ISBN 0-8137-2356-6).

Koeberl, C., and Montanari, A. (eds.) (2009) The Late Eocene Earth: Hothouse, Icehouse, and Impacts. *Geological Society of America, Special Paper* **452**, 322 + viii pp (ISBN 978-0-8137-2452-2).

Science Editor, Geological Society of America Bulletin, 2009-2015
Science Editor, Geological Society of America Books, 2016 ff

AWARDS AND HONORS
• 1994 – Fellow of the Meteoritical Society
• 2000 – Fellow of the Geological Society of South Africa
• 2006 – elected Full Member of the Austrian Academy of Sciences
• 2006 – Asteroid (15963) named "Koeberl"
• 2007 – Barringer Medal and Award of the Meteoritical Society
• 2012 – Fellow of the Geological Society of America

IMPACT EVENTS IN EARTH HISTORY: THE CRETACEOUS-PALEOGENE BOUNDARY EJECTA LAYER AND ITS SOURCE CRATER AT CHICXULUB

Christian Koeberl

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Impact cratering is a high-energy event that occurs at more or less irregular intervals. Impacts had been very important during the formation and the early history of the Earth. The oldest known impact record on Earth are spherule layers in South Africa and in Australia with ages of 3.4 Ga and younger. The oldest known impact structures of Earth are about 2 billion years old. More recently, impacts have occurred on Earth often and left scars in the form of impact craters; so far about 200 of them have been identified although many more must have formed.

At the Cretaceous-Paleogene (K-Pg) boundary, the discovery of an extraterrestrial signature, together with the presence of shocked minerals, led not only to the identification of an impact event as the cause of the end-Cretaceous mass extinction, but also to the discovery of a large buried impact structure about 200 km in diameter, the Chicxulub structure. There are several lines of evidence that indicate a large-scale impact event at that time, such as elevated platinum-group element (PGE) contents, inter-element PGE ratios identical to those of meteorites, Cr and Os isotopic composition, the presence of various shocked minerals, etc. Chicxulub has been distinctly linked with the K-Pg e3jecta on the basis of isotopic signatures and age data.

The Chicxulub impact crater, Mexico, is unique. It is the only known terrestrial impact structure that has been directly linked to a mass extinction event. It is the only one of the three largest impact structures on Earth that is well-preserved. It is the only known terrestrial impact structure with an unequivocal topographic "peak ring." Chicxulub's role in the K-Pg mass extinction and its exceptional state of preservation make it an important natural laboratory for the study of both large impact crater formation on Earth and other planets, and the effects of large impacts on the Earth's environment and ecology. Effects of the large impact event at Chicxulub range from minutes to millennia and include a variety of short-term and severe environmental perturbations.

In an ICDP-project, borehole Yaxcopoil-1, was drilled from December 2001 through March 2002 into the lower part of the post-impact carbonate sequence, the impact breccias, and the displaced Cretaceous rocks.

A new drilling project at Chicxulub by ICDP and IODP was conducted in 2016. The goal was to address several questions, including: 1) what is the nature of a peak ring, 2) how are rocks weakened during large impacts to allow them to collapse and form relatively wide, flat craters, and 3) what caused the environmental changes that led to a mass extinction? Our understanding of the impact process is far from complete, and the first two questions represent fundamental gaps in our knowledge. Despite over 30 years of intense debate, we are still striving to answer the third question. A principal objective of the proposed drilling is to understand the fundamental impact process of peak ring formation. Drill hole Chicx-03A was intended to sample material that forms a topographic peak ring, and reveal the lithological and physical state of these rocks, including porosity, fracturing and extent of shock effects. IODP expedition 364 took place 5th April to 6th June 2016 and was highly successful. The studies of the rocks contribute to our understanding of such a large-scale impact event and the relation to the K-Pg mass extinction.

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EDUCATION

1980 Diploma Degree in Geology, Ludwig-Maximilians-University, Munich

CAREER

1981-1989 Research fellow, post-doc, scientific assistant (~equiv. Assistant Professor) at the Institut für Geowissenschaften (Paläontologie) at Johannes Gutenberg-University Mainz;
1989-1998: Univ-Professor of Geology and Paleontology at the Institute of Geology und Paleontology at the University of Stuttgart
1998-2005: Full Professor, Chair of Paleontology and Historical Geology; Director of Bavarian State Collections of Paleontology and Geology, from 2003-2005: General Director of Bavarian Natural History Collections.
2006-2011: Director General and Professor, Museum für Naturkunde (Museum of Natural History; until Dec. 2010) & Full Professor of Geobiology at Institute of Biology, Humboldt-University, Berlin
2012- recent: Member of the IUGS/ICS Working Group on the 'Anthropocene'
2012-recent: Full Professor of Invertebrate Palaeontology and Geobiology at Freie Universität Berlin, Working Group Geobiology and Anthropocene Research
2014-2016: Founding Director of Haus der Zukunft / Futurium gGmbH, Berlin

RESEARCH INTERESTS

Earth History, Evolution & Ecology of Reefs, Anthropocene, Museology, Science Communication

PUBLICATIONS AND SERVICES

Recent publications encompass a broad array on Anthropocene topics, from research papers to science comics. Other services include conceptionalizing and (co-)curating science exhibitions, and policy advisory reports.

AWARDS AND HONORS (select.)

1986: Prize of Johannes Gutenberg University Mainz, for phD-Dissertation
1998: Werner und Inge Grüter Award for IYOR 1997 activities
2008: Berlin Bear – Culture Award for new exhibitions at Museum für Naturkunde, Berlin
German Multimedia-Award (for relaunch of Museum für Naturkunde, with Art+Com)
Since 2008*:* Corresponding member of the Bavarian Academy of Science
2008-2013: Member of the German Advisory Council on Global Change to the German Government (WBGU)
2011- 2014: Carson Fellow, then Affiliate Carson Professor at the Rachel Carson Center for Environment and Society, Munich.

WELCOME TO THE ANTHROPOCENE - THE EARTH IN OUR HANDS

Reinhold Leinfelder
WG Geobiology and Anthropocene Research, Freie Universität, Berlin, Germany

The geochronological epoch of the Holocene, commencing at ca. 11,700 years before present, provided humans with stable environmental conditions, having allowed them to settle down in the Neolithic Revolution, living from agriculture, and enabling further differentiation into modern societies, as characterized by *e.g.* urban settlements, division of labour, infrastructures, as well as regional and – later – global trade. All this also laid a foundation for the Industrial Revolution in the late 18th and early 19th century.

However, both the Neolithic Revolution and especially the Industrial Revolution had a huge, and since the mid-20th century exponentially increasing influence on the Earth system. Today, humans have become a dominant Earth system factor by changing biomes into anthromes – 77 % of the ice free terrestrial area is not pristine any more (Ellis 2011); accelerating erosion and sediment transport by a factor of 10-30 relative to the average of the last 500 million years (Wilkinson 2005); controlling and regulating most of the fluvial water systems (*e.g.* Meybeck & Vörosmarty 2005), trapping sediments through tens of thousands of dams (Syvitski & Kettner 2011); causing climate change by consuming copious amounts of fossil energy resources within a few 100 years which took 400 million years to form - and in response raising sea levels and acidity of the oceans (*e.g.* WBGU 2011). We accelerate species extinction rates at least by a factor 10 to 100, if not 1000 times greater than during the life span of Earth history, and we dominate biota by producing vast amounts of biomass through crop plants, pets and livestock, with 24% of NPP and up to 90 % of mammal biomass being anthropogenic - the latter including living humans, living pets and living farmed animals (Williams *et al*. 2016, Steffen *et al*. 2016, also for further refs.). In addition, we dominate the reactive nitrate and phosphate cycles, created fallout of radioactive particles as well as industrial fly ash (Steffen *et al*. 2015, Waters *et al*. 2016), and produced about 8.3 billion metric tons of plastics, from which we dumped about 60% into the environment (both in waste dumps and uncontrolled, incl. oceans) (Geyer *et al*. 2017). In total, we have so far created the incredible amount of ca. 30 trillion tons of technosphere, including concrete and brick houses, machines, elementary aluminium, plastics, glass, artificial grounds and much more (Zalasiewicz *et al*. 2017a). This legacy attributes about 4000 metric tons of technosphere to every single human presently living on Earth. All this identifies humankind not only as an Earth system factor, but also as a very influencial geological force, completely changing depositional patterns and composition of sediments. Both together, *i.e.* the Earth system shift away from the stable state of the Holocene, and the new and globally spread array of new technofossils and geosignals makes it plausible to terminate the Holocene in the mid 20th century, and have it followed by the Anthropocene, the "human-made New" (see Crutzen & Stoermer, 2000, Crutzen, 2002, Waters *et al*. 2016, Zalasiewicz et. al. 2017b).

Such a new distinction of an Anthropocene Earth history epoch is not only feasible and appropriate when seen in the focus of sedimentary characteristics and Earth system change, but it also allows for a more integrative, systemic view on Earth system development and processes by adding an Anthroposphere to the Earth system spheres, and by reflecting mutual interactions of all spheres. The Anthropocene concept also fosters interdisciplinary cooperation outside the field of geoscientists, *e.g.* with historians, archaeologists and biologists, by jointly evaluating human-recorded, calendar-based historical archives and geologically recorded sedimentary and biological archives. In addition, the state of the present Anthropocene as well as the knowledge

on how it has been caused, is a strong instigation for better monitoring Earth system changes as well as for developing a polyspectric array of possible and desirable societal and economic pathways into the future within a safe operating space that would be compatible with a fully functionable and habitable future Anthropocene Earth system (Leinfelder 2016a, Zalasiewicz *et al*. 2017c).

On the search for such polyspectric futures, a systemic view onto the Anthropocene sees the extent, interaction, temporal and spatial dynamics of today's processes not only as challenges, but also as chances for new conceptual approaches in school and life-long education (*cf*. Leinfelder 2013). Such approaches could include new narratives of our embedding in the Earth system, such as the one on the importance of environmental stability of the Holocene for societal development (as highlighted above), or the "Hall of Fame"-narrative of Earth history: Humans are not the first organisms causing paradigm shifts in the Earth system. Among these are (1) archaic methane bacteria warming up the climate of the early Earth which suffered from a still weak solar insolation; (2) iron bacteria depleting oceans from masses of dissolved iron, thus producing the vast majority of all iron ores (banded iron formations) around 3-2,5 billion years before present; (3) cyanobacteria producing accelerated amounts of oxygen from 2,5 billion years onwards and removing surplus of calcium ions from the oceans by calcifying their microbial sheaths to form stromatolites, both of which allowed for the evolution of metazoan lives. (4) Metazoans with calcareous skeletons, such as reef corals, removed enormous amounts of CO_2 from the oceans and the atmosphere by producing limestones, thus stabilizing the climate. (5) Early forests producing large masses of coals, removed CO_2 from the atmosphere and thus triggered an ice age about 320 million years ago; (6) plankton and their predators, being trapped in anoxic waters also transferred huge amounts of CO_2 as organic matter into sediments which converted to oil and gas, as well as phosphates; and (7) grass started (still in the age of the dinosaurs, but especially after their extinction) to become the number one feed, since it was the first to simply keep on growing when grazed on, unlike bushes or trees, which either would die or would have to wait for the next vegetation period when eaten bare. Grass was the prerequisite not only for the long gathering and hunting episodes of early humans in savanna lands but especially necessary to settle down to cultivate crops and feed livestock. Without the evolutionary origin of grass and without all the non-renewable resources provided from ancient life activities, our present human societies would be very different.

This is yet another example how Earth history could be retold in an Anthropocene context, embedding us much better into Earth history by understanding that it is not only the present landscape which feeds us, but it is the non-renewable resources, including iron, copper, RE, sand, limestones, phosphates etc. that enable our technology and our modern way of life (*cf.* Zalasiewicz *et al*. 2017a). In this way, the Anthropocene view not only allows for localising ourselves within Earth history and the present Earth System, it also highlights our interconnectivity both on an economic and a societal scale, can raise awareness and, given suitable education projects, self-efficacy. On a metalevel the concept might also have the capacity to open views towards a, culturally and societally very complex, world citizenship and raise the responsibility level towards integrating humanity in a symbiontic way into the Earth system rather than using it up like a parasite (Leinfelder 2016b).

The complex concept of the Anthropocene hence represents a multilevel concept, with two scientific base levels, *i.e.*, the Earth system analysis, and the geological analysis. However, it triggers a superimposed consequential metalevel of new integrated views, responsibilities and ethical aspects, interconnectedness, societal transformation, and knowledge-based careful

design of the future Earth. It is certainly not necessary to see the Anthropocene as another one of the grand humiliations to the human world view (such as the Copernican, Darwinian and Freudian humiliations), as some see it. On the contrary, Anthropocene studies and metalevel reflections are expected to help develop a much better view of our influence on and interaction with this planet, and change this influence from harmful to one of mutual symbiotic benefit. Having the world in our hands, and better understanding this world should indeed allow us to welcome the Anthropocene.

Literature

Crutzen, P.J. (2002): Geology of mankind. Nature 415, 23.

Crutzen, P.J. & Stoermer, E.F. (2000): The "Anthropocene". Global Change Newsletter, 41, 17-18.

Ellis, E.C. (2011): Anthropogenic transformation of the terrestrial biosphere. Philosophical Transactions of the Royal Society, A369, 1010-1035.

Geyer, R., Jambeck, J.R. & Law, K.L. (2017): Production, use, and fate of all plastics ever made. Sci. Adv., 3 (7), e1700782, DOI: 10.1126/sciadv.1700782

Leinfelder, R. (2013): Assuming Responsibility for the Anthropocene: Challenges and Opportunities in Education.- In: Trischler, H. (ed.), Anthropocene - Envisioning the Future of the Age of Humans, RCC-Perspectives, 2/2013, 9-18, Rachel Carson Center, Munich. DOI:10.5282/rcc/5603

Leinfelder, R. (2016a): Das Haus der Zukunft (Berlin) als Ort der Partizipation. In: Popp, R. (Hrsg.), Einblicke, Ausblicke, Weitblicke. Aktuelle Perspektiven der Zukunftsforschung,74-93, Berlin, Wien etc. (LIT-Verlag).

Leinfelder, R. (2016b): Vom Parasitismus zur Symbiose. Zu den drei Hauptebenen des Anthropozäns. Politik & Kultur 3/16, S. 20 (Deutscher Kulturrat).

Meybeck, M. & Vörösmarty, C. (2005). Fluvial filtering of land-to-ocean fluxes: from natural Holocene variations to Anthropocene.- C.R. Geoscience, 337, 107-123, DOI:10.1016/j.crte.2004.09.016

Steffen, W., Leinfelder, R., Zalasiewicz, J., Waters, C. N., Williams, M., Summerhayes, C., Barnosky, A. D., Cearreta, A., Crutzen, P., Edgeworth, M., Ellis, E. C., Fairchild, I. J., Galuszka, A., Grinevald, J., Haywood, A., Sul, J. I. d., Jeandel, C., McNeill, J.R., Odada, E., Oreskes, N., Revkin, A., Richter, D. d. B., Syvitski, J., Vidas, D., Wagreich, M., Wing, S. L., Wolfe, A. P. and Schellnhuber, H.J. (2016): Stratigraphic and Earth System Approaches to Defining the Anthropocene. Earth's Future, 4 (8), 324-345, DOI:10.1002/2016EF000379

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B. & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. Science, Vol. 347, Issue 6223, DOI: 10.1126/science.1259855

Syvitski, J.P.M. & Kettner, A. (2011): Sediment flux and the Anthropocene.- Phil. Trans. R. Soc. A, 369, 957-975, DOI:10.1098/rsta.2010.0329

Waters, C.N., Zalasiewicz, J., Summerhayes, C., Barnosky, A.D. Poirier, C., Galuszka, A., Cearreta, A., Edgeworth, M., Ellis, E.C., Ellis, M., Jeandel, C., Leinfelder, R., McNeill, J.R. Richter, D. de B., Steffen, W., JSyvitski, J., Vidas, D., Wagreich, M., Williams, M., Zhisheng, A., Grinevald, J., Odada, E., Oreskes, N., Wolfe, A.P. (2016): The Anthropocene is functionally and stratigraphically distinct from the Holocene.- Science, 8 January 2016: Vol. 351 no. 6269, DOI: 10.1126/science.aad2622

WBGU (2011): World in Transition – A Social Contract for Sustainability.- Flagship Report, German Advisory Councal on Global Change (WBGU), 400 p., Berlin. wbgu.de/en/flagship-reports/fr-2011-a-social-contract/

Wilkinson, B.H. (2005): Humans as geologic agents: A deep-time perspective.- Geology, 33 (3), 161-164, DOI:10.1130/G21108.1

Williams, M., Zalasiewicz, J., Waters, C. N., Edgeworth, M., Bennett, C., Barnosky, A. D., Ellis, E. C., Ellis, M. A., Cearreta, A., Haff, P. K., Ivar do Sul, J. A., Leinfelder, R., McNeill, J. R., Odada, E., Oreskes, N., Revkin, A., Richter, D. d., Steffen, W., Summerhayes, C., Syvitski, J. P., Vidas, D., Wagreich, M., Wing, S. L., Wolfe, A. P. and Zhisheng, A. (2016): The Anthropocene: a conspicuous stratigraphical signal of anthropogenic changes in production and consumption across the biosphere. Earth's Future, 4, 34-53 (Wiley) DOI: 10.1002/2015EF000339

Zalasiewicz, J., Williams, M., Waters, C.N., Barnosky, A.D., Palmesino, J., Rönnskog, A.S., Edgeworth, M., Neil, C., Cearreta, A., Crutzen, E., Fairchild, I.J., Grinevald, J., Haff, P., Ivar do Sul, J.A., Jeandel, C., Leinfelder, R., McNeill, J.R., Odada, E., Oreskes, N., Price, S.J., Revkin, A., Steffen, W., Summerhayes, C., Vidas, D., Wing, S., & Wolfe, A.P. (2017a): Scale and diversity of the physical technosphere: A geological perspective. The Anthropocene Review, 4 (1), 9-22 DOI:10.1177/2053019616677743

Zalasiewicz, J., Waters, C.N., Summerhayes, C.P., Wolfe, A.P., Barnosky, A.D., Cearreta, A., Crutzen, P., Ellis, E., Fairchild, I.J., Galuszka, A., Haff, P., Hajdas, I., Head, M.J., Ivar do Sul, J.A., Jeandel, C., Leinfelder, R., McNeill, J.R., Neal, C., Odada, E., Oreskes, N., Steffen, W., Syvitski, J., Vidas, D., Wagreich, ;M. & Williams, M. (2017b): The Working Group on the Anthropocene: Summary of evidence and interim recommendations. Anthropocene, DOI:10.1016/j.ancene.2017.09.001

Zalasiewicz, J., Steffen, W., Leinfelder, R., Williams M., & Waters, C.M (2017c): Petrifying earth processes .-Theory, Culture & Society, 34(3-2), 3-23. DOI: 10.1177/0263276417690587

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EDUCATION

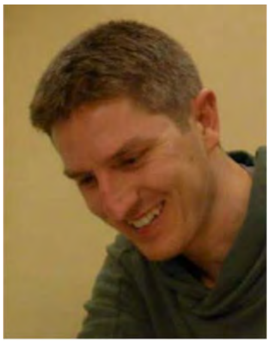
Master Degree in Electrical Engineering (University of Rome *La Sapienza*). PhD on the subject of optical-radar remote sensing for the monitoring of surface deformation (University of Toulouse *Paul Sabatier*)

CAREER

After his Master Degree, he was hired in 1990 at the Operation Center of the European Space Agency in Germany (ESA/ESOC) in the area of mission analysis and orbit control manoeuvre optimization. He then moved to precise orbit determination and to orbit and attitude control and continued his career at ESA/ESTEC in The Netherlands.

In 1997, he moved to CESBIO and then to CNES, Toulouse, where he worked for his PhD while working as a Project Manager for the *International Charter on Space and Major Disasters*, conducting R&D activities for remote sensing applications to disaster management and natural risk monitoring, interferometric monitoring of several seismic areas and providing training courses in Earth Observation.

After a short period at Italian Space Agency (2001) as a technical interface ASI-CNES for the cooperation COSMO-SkyMed / Pléiades, he joined ESA/ESRIN, in Italy, working in Earth Observation applications; since 2007, he coordinates the Education and Training Activities in Earth Observation.



Chris Stewart
RSAC Consultant
Science, Applications and Climate
Earth Observation Programmes
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Chris.Stewar@esa.int

Having completed a Batchelor's degree in mathematics, Chris Stewart specialised in Remote Sensing and Image Interpretation at Edinburgh University where he obtained his Master's in 2002. Chris then began his professional career at Remote Sensing Applications Consultants (RSAC) Ltd in the UK. At RSAC he supported, among other projects, the Remote Sensing Control of Area-Based Subsidies projects in England and Wales.

Since 2007 Chris has been providing consultancy support to the European Space Agency (ESA), based full time in ESA/ESRIN in Frascati. At ESRIN his tasks include technical and management support to projects in the Science, Applications and Climate Department of the ESA Earth Observation Programmes Directorate.

In May 2017, Chris received from the Tor Vergata University of Rome a PhD with distinction in Archaeological Prospection using Spaceborne SAR. From March 2018, Chris will take up a Research Fellowship position at ESA in Earth Observation Exponential Technologies. During his Research Fellowship he will study the application of deep learning and crowdsourcing for EO based archaeological prospection.

HOW EARTH OBSERVATION (EO) FROM SPACE CHANGED OUR KNOWLEDGE OF THE PLANET

Francesco Sarti and Chris Stewart
ESA/ESRIN

Earth Observation from space provides valuable information on our planet. A synoptic view of the Earth is often the only way to understand processes taking place in the hydrosphere, biosphere, atmosphere and geosphere. Moreover, it enables us to understand how these systems are connected. The ability of Earth observation to provide regular global monitoring is essential to comprehend the nature in which changes take place in rapid processes, such as weather, and more gradual and long term processes, such as climate change. In this way we can extrapolate into the future to help ourselves to better prepare for possible consequences and mitigate their effects.

If Earth Observation had been possible in past centuries, tremendous effort, time, resources and loss of life on formerly challenging mapping initiatives would have been saved. Until the late 19th Century, for example, the source of the River Nile was an enigma that baffled the western world. Many costly expeditions were launched that frequently resulted in failure. Today, not only is it possible to map and understand the longest river in the world, together with all its tributaries, in an instant, with the help of one geostationary satellite image, but we can also monitor any changes due to events which may be either natural (such as drought and flooding) or man-made (such as the construction of dams). Another good example of a cartographic challenge that squandered the fortunes of many nations includes the search for a Northwest passage through the Arctic. If Earth Observation had been available in earlier times, many disastrous expeditions would have been avoided by a simple observation that the passage was almost always too choked with ice. Now however, with frequent monitoring, we can observe that the Northwest passage is becoming increasingly navigable. We can deduce that this fact, while providing an opportunity for navigation, is an indication of climate change, which brings also negative consequences. Aside from *cartography* and *navigation*, there are many other benefits of a synoptic view of the world that Earth Observation can provide. Some other examples include *geography*, *topography*, *ocean colour*, *salinity*, *bathymetry*, *snow cover and soil moisture*.

Figure 1. Optical satellite image mosaic with River Nile overlain in blue. Credits: Stratfor 2014.

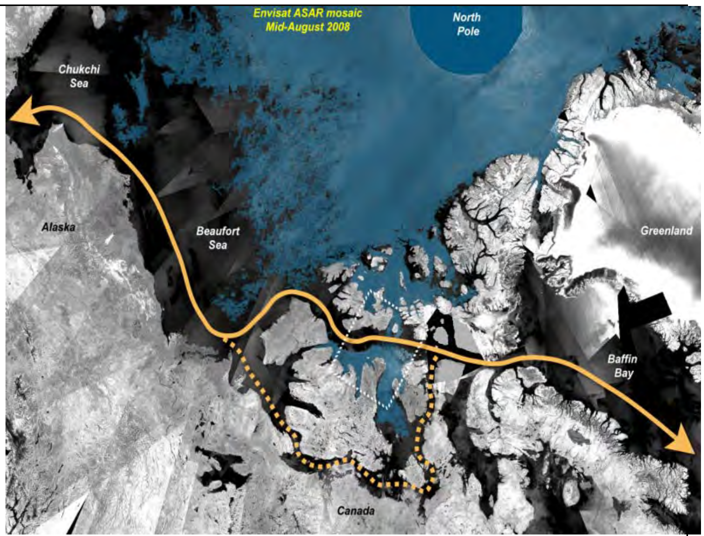

Figure 2. Radar satellite image mosaic from August 2008 showing momentarily ice free Northwest passage through the Arctic. Credits: ESA

Through Earth Observation we have attained a better understanding of the dynamic nature of

the Earth and its processes. For example, *atmospheric phenomena like winds, meteorology, climate, ozone variations*, change at high temporal and spatial rates. In order to understand how these *dynamic processes* behave, simultaneous global monitoring at a high temporal frequency is essential. Most of the input to numerical weather prediction comes from Earth Observation satellite data, in both geostationary and low Earth orbits. Combined with in-situ data, the satellite data is used by models to forecast the weather. Moreover, a long term archive of satellite EO data can also provide us with a better understanding of our changing climate. Dynamic changes are not limited to the atmosphere, the *oceans* also are characterised by highly dynamic phenomena. *Ocean currents* for example are in a state of continuous flux, in both space and time. These can be monitored with a combination of instruments including those that measure the temperature of the sea surface, its height, and even the gravitational sphere of the Earth, or geoid. The geoid tells us how the sea surface height should look were there no currents and other dynamic phenomena. If we subtract this from direct measurements of the sea surface height, we see the variations due to dynamic changes, including currents. Measurements of oceanic parameters are essential to detect phenomena such as possible *tropical storms and hurricanes, El Nino and La Nina events*, and others.

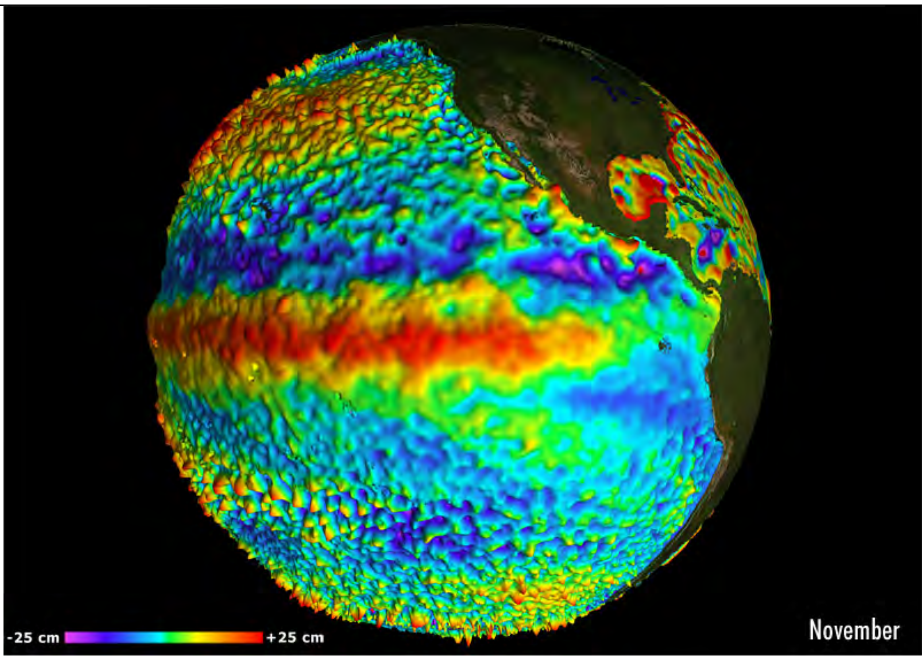

Figure 3. Sea surface height positive anomalies measured by altimetry satellites in November 2009. Credits: MyOcean.

The debate taking place today on the *anthropogenic influence* on climate change can have huge impacts on the decisions we may make to alter our behaviour in order to mitigate potential future situations. Earth Observation plays an essential role in this debate, providing reliable measurements of climate indicators and evidence of human activity, such as *deforestation, urbanisation, and carbon emissions*. These combined measurements of climate indicators and human activity can then be correlated to detect any potential conversion of evidence that may influence our perceived impact on the environment and planet as a whole.

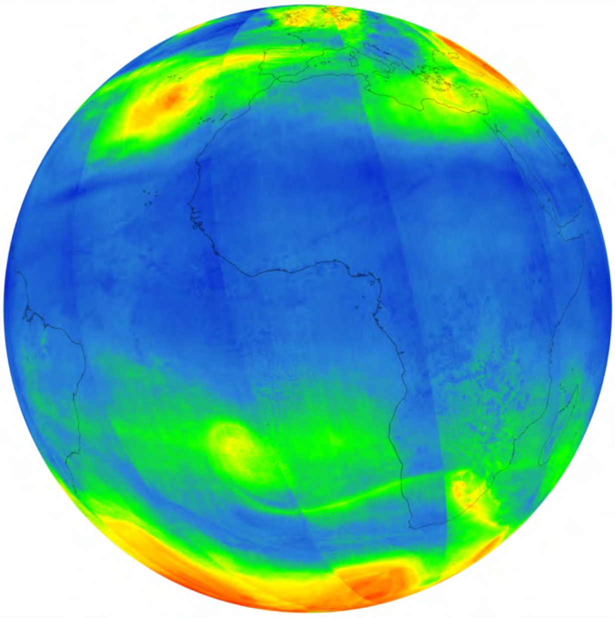

***Figure 4**. One of the first images from the Copernicus Sentinel-5P mission shows how ozone is distributed around the world. Credits: Contains modified Copernicus Sentinel data (2017), processed by DLR/ESA*

Any decisions we take regarding alterations to our behaviour need to be monitored, not only to aid enforcement, but also to assess their impact. Earth Observation is often the most efficient tool for such monitoring. For example, *protected areas and UNESCO Natural and Cultural Heritage Sites* can be monitored, and the achievement of many of the *UN Sustainable Development Goals* can be aided through Earth Observation.

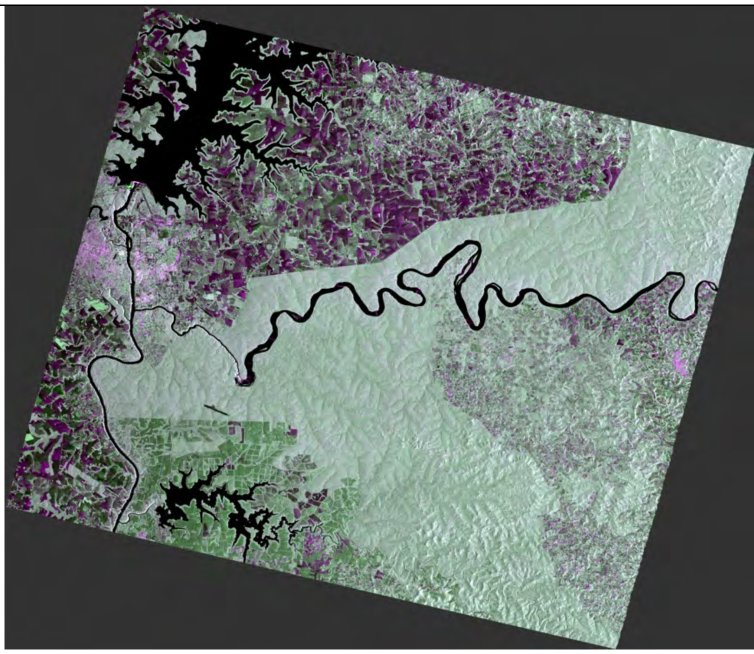

Figure 5. Sentinel-1 satellite radar image of the Iguazu national park, showing the boundary of the protected forest stretching over three countries: Brazil, Argentina and Paraguay. Credits: Contains modified Copernicus Sentinel data (2016).

Finally, Earth Observation is an invaluable tool for *education and outreach*, to prepare the *future generation* of decision makers to understand key issues related to the health of our planet and its resources. Earth Observation for example can illustrate key concepts related to the use of water resources, agricultural practices, land use changes, and other issues that will become ever more critical as the population of the Earth, and corresponding demand for resources, increases.

Manuel Pubellier
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manupub.pubellier@gmail.com

Education

1999 HDR in Geosciences (U. P&M Curie)
1984 PhD in Geosciences
1982 Master (Geology)

Professional appointments

2018 President of CGMW (Com for the Geological Map of the World
2015-2018 Director of Research 1st Class at CNRS / ENS; Head of Geology/Geophysics/Geodesy team
2011-2013 Dean of the University Technogy of Petronas, Perak, Malaysia, and MA6 "Star" Professor
2011-2014 CNRS Researcher at Ecole Normale Supérieure (ENS)
2006 Researcher (secondment) at TOTAL E&P Paris
1995-2012 Researcher CNRS at Ecole Normale Supérieure (ENS) ; Director of Research in 2013
1988-1995 Researcher at Univ. P&M Curie
1984-1986 Lecturer in Geology (EMTG, Port au Prince, Haïti).

Interests

Geodynamics and structural geology of margins onshore and offshore, sattelite imagery and seismic interpretation, GIS. Link between geophysics and field geology. Link between academia and industry

Main projects

Exploration in active geodynamic settings, ODP drillings, Bathymetry and seismic marine exploration, mapping of plate boundaries, expert in geology of tropical regions – Caribbean and SE Asia since 1987

Services over the last 10 years:

Geological Society of France, Assistant Editor 1988-1991, Vice President 1991-92
Occasional or regular member of AGU, EGU, AAPG, SEP, EAGE
2007-2011 Editor of the IGMA5000 (International Geological Map of Asia at scale 1/5M) for CGMW and UNESCO
2007-20011 Coordinator and Secretary General of CGMW, Member of DIMAS (Int Gp for geological Map standards)
Member of the Steering Committee of OneGeology International Project
Consultant for Oil and Mining industry project with Geolines

Responsabilities in education and national/international projects over the last 10 years :

PhD-Msc supervision:
Supervisor of 28 PhD thesis, and 17 MsC students

Lectures

2013-2018- Lectures at ENS and P11
2011-2013 Full time University Professor at UTP Malaysia
2006-2009 Occasional : Universiti Teknologi Petronas Malaysia, Geodynamics, Regional and Petroleum basins of SEAsia, Structural geology, Introduction to Petroleum Geosciences, Mapping ans Remote sensing for FYP
1994-2009, IFP school, France, Geology, tectonics, Geodynamics, Sedimentology, Stratigraphy
2005-2008 Invited Professor Graduate School of Chinese Acad of Sciences, China, Geodynamics and Geology of China and Asia,
2005-2010, University of Hong Kong, DES; Field Training, Lectures in remote sensing
1997-2011-ENS- Ecole Normale Supérieure: Tectonics, Geodynamics, Remote sensing, Field training in France, Italy, USA,
1990-1997 University of Paris 6, Masters Level, Geodynamics, Remote sensing, Geo-environments
1984-1986 Ecole Moyenne de Techniciens Géologues; Haïti; Lectures in Geology, and field courses

Organisation of international meetings

Organiser of International Workshops (GEOSEA, ESTCON-ICIPEG2014),
convenor of sessions at International congresses (AGU, EGU, IGC34, IGC35, AAPG). Many keynote speeches at international conferences. 6 Special sessions at EGU and AGU meetings Int. Workshops ; South China SeaInt Workshop on the Tectonic Map of the Arctic- TeMar project 2014 and 2017 (Paris)
Organisation of GA of CGMW special sessions at IGC 2012 and 2016

Publications

362 publications in peer review international journals and international abstracts, 14 Geological Maps and Atlases

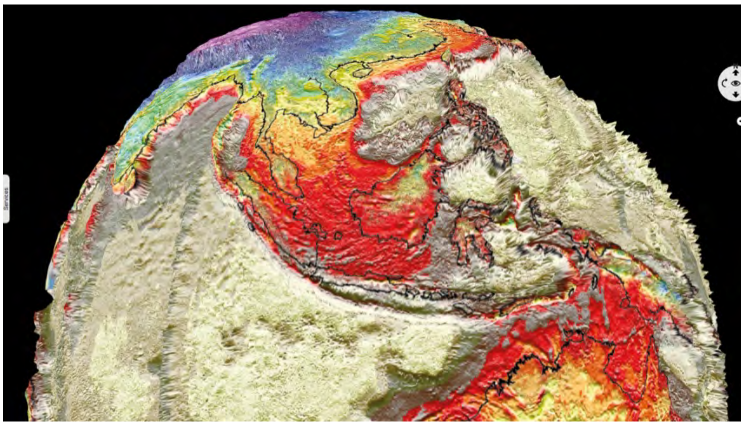
VTWEB, A SIMPLE TOOL FOR TEACHING USING MAPS

Manuel Pubellier
École Normale Supérieure, Paris, France
Serge Riazanoff
Visio Terra, Champs-sur-Marne, France

The CGMW is an international non-profit association governed by French law and is responsible for designing, coordinating, preparing and publishing small-scale thematic Earth Science maps of the globe, continent, major regions and oceans. The CGMW is affiliated to the International Union of Geological Sciences (IUGS) and the International Union of Geodesy and Geophysics (IUGG), and is supported by UNESCO. It pursues its scientific and educational task as a non-governmental scientific organization supported by the geological surveys of the World, aiming at the diffusion of maps in Geosciences.

CGMW is also fostering modern and user friendly tools to diffuse maps so that they can reach the most remote parts of the World. The VtWeb tool (*http://visioterra.org/VtWeb/)* is a free 3D visualization tool which does not require any software download and can instantly display CGMW maps on a map, a globe with digital topography, or on the geoïd.

It becomes easy to teach in an entertaining way the relationships between the topography and the geology, the evolution of the oceans and the continents, and geophysics to students at any level.



ICEMAP

AN INTERACTIVE STORYTELLING EXPERIENCE BASED ON FOREFRONT SCIENCE

Maja Sojtaric, Henry Patton, Mona Holmø, Alun L. Hubbard
UiT The Arctic University of Norway
Nordnorsk vitensenter Tromsø

A massive ice sheet - over 2km thick - covered most of northern Eurasia around 24,000 years ago. Based on recently published model reconstructions of this last ice age, we have created an interactive map-based story called ICEMAP. Through a multi-layered interactive web page, as well as a physical installation at the Science Centre in Tromsø, Norway, school-children can explore how this powerful ice mass dramatically transformed Europe at a time when humans first populated the continent. Children and teachers can interact with the ice age simulation to explore how the ice sheet grew and melted, and experience how the changing environment around Europe affected our narrator Lenny Lemming* - a cartoon avatar that travels through thousands of years of climate change.

ICEMAP is an innovative take on data visualization targeted towards children of all ages, combining a cutting-edge numerical ice-sheet reconstruction with narrative illustrations to convey knowledge about how the complex natural world around us functions, changes and leaves a lasting geological legacy. The cartoon guide provides an accessible and relatable narrative, while the simulation gives students first-hand experience with model outputs and a glimpse into the powerful impacts of ice sheet glaciation and sea level change.

ICEMAP is based on published and ongoing work by scientists at a Norwegian Centre of Excellence, CAGE.

“TEACHERS AT SEA” IN THE PHILIPPINE SEA

Glaiza Reobilo and Carlo Laj
Philippine Science High School, Bicol Region Campus &
EGU Committee on Education

With their 4 colleagues who are not attending this GIFT workshop, but will participate to the cruise, Glaiza Reobilo and Carlo Laj invite you to follow their oceanographic cruise in the Philippine Sea on board the French Research Vessel Marion Dufresne. We will be in almost daily contact via email with all the teachers who will give us their address, and in a second time we will distribute freely to all of them the video that will be produced on the scientific and daily life on board the ship. Come on board!

Geological trail
from Maria Theresa's Monument
to St. Stephen's Cathedral
11th April 2018, 14.00 – 15.30