Ciências da Terra (UNL)	Lisboa	Nº 18	pp. 43-48, 1 fig.	2013

Teaching of Stratigraphy, geological heritage and Geoethics State of the art

Jesús Martínez-Frías[1] & Patrick de Wever[2]

[1] Centro de Astrobiología, CSIC-INTA, associated to the NASA Astrobiology Institute, Ctra de Ajalvir, km. 4, 28850 Torrejón de Ardoz, Madrid (Spain): jmfrias@cab.inta-csic.es
[2] Muséum National d'Histoire Naturelle, 43 rue Buffon F-75 005 Paris Cedex 05 (France): patrick.de-wever@mnhn.fr

Summary

Stratigraphy is one of the most remarkable geoscientific disciplines. Many activities related to stratigraphy have extremely significant implications in geoeducation and geological heritage, and also require a geoethical approach. This contribution provides a short and general review regarding these three subjects their relation with Stratigraphy. If geoscience education is a key factor in the academic, scientific and professional progress of any modern society, geoethics is gaining a great importance with the emergence of topics such as the Anthropocene, marking the evidence and extent of human activities and their possible significant global impact. Likewise, geological heritage are geological features with global, national, or local importance and geological sites that represent processes (magmatic segregation, metamorphism, dissolution, weathering, etc.) or a testimony of the of Earth's history (palaeontology, global tectonics, sea level, stratigraphy). Geoeducation, geological hertitage and geoethics are three pillars which are of crucial importance, and which must be jointly considered.

Keywords: Geoscience education, geological heritage, geoethics, state-of-the-art

Introduction

Since the classical and pioneer works by Nicolas Steno, William Smith, Georges Cuvier and Alexandre Brongniart, it can be said that nowadays Stratigraphy is one of the most remarkable geoscientific disciplines which, besides mantaining the classical field principles, has also been able to incorporate new techniques and methods, facing the most vanguardist geoeducational challenges (e.g. planetary stratigraphy – see Session 7 STRATI2013). As Prof. Amos Salvador, former Chair of the International Subcommission on Stratigraphic Classification (ISSC) for fifteen years (1977-1992) and author of the second edition of the International Stratigraphic Guide, stated: *"Stratigraphy is the foundation on which most geological studies are built"...·Some of the most important recent advances in the understanding of geological history have been made as a result of the integration of several different stratigraphic approaches: lithostratigraphy, biostratigraphy, magnetostratigraphy, geochronometry, etc."..."Stratigraphy should be one of the fundamental core courses in the education of geologists, and the different approaches and tools of stratigraphy need to be taught together"*

(Salvador, 1997). In accordance with the USGS, Stratigraphy is the "*Branch of geology concerned with the study of the formation, composition, ordering in time, and arrangement in space of stratified rocks*". A more complete and generally accepted definition of Stratigraphy can be found in Murphy & Salvador (2010): *" Stratigraphy, from Latin stratum + Greek graphia, is the description of all rock bodies forming the Earth's crust and their organization into distinctive, useful, mappable units based on their inherent properties or attributes in order to establish their distribution and relationship in space and their succession in time, and to interpret geologic history".* Many activities of the International Commission on Stratigraphy (ICS) - the largest and oldest constituent scientific body in the International Union of Geological Sciences (IUGS) - have extremely significant implications in geoeducation and geological heritage, either directly or by the particular working of its subcommissions. Likewise, an increase of the relevance and awareness of ICS work in the field of educational and applied stratigraphy has been clearly and oficially expressed (ICS, 2010). Now, Geoethics is, for the first time, also interacting with this remarkable geoscientific subject, through the collaboration of the International Association for Geoethics (IAGETH).

Teaching and geoscience education

Geoscience education is a key factor in the academic, scientific and professional progress of any modern society (Martinez-Frias & Mogessie, 2012). Reviews of geoscience education and geoscience educational research have been undertaken only relatively recently. One of the first overviews was provided by Ault (1994). The first international conference of geoscience education took place in 1993 (Stow & McCall, 1996), with just a small component of research-based presentations (King, 2008). Despite the long academic tradition and significance of Stratigraphy, a recent work carried out by Herrera & Ricks (2013) shows how the geoscience education literature addressing students' understanding of the fundamental concepts of sequence stratigraphy is relatively thin, and the subject has not been well explored. A detailed search in the Scientific Thomson Reuters' Web of Science (WoS) database including the keyword "Stratigraphy" for papers published in the period 1900–2013, yields more than 24 000 references (24 848) including this term. Regarding the main subjects, it is important to note that nearly 54% (53.92%) are incorporated in the WoS' Category of "Geosciences Multidisciplinary", around 21% (20.79%) in the Category of "Geology" and more than 16% (16.41%) in the Category of Paleontology. Considering the source titles (journals) the five maximum record counts correspond to the journals *Paleogeography, Paleoclimatology and Paleoecology* (917 records), *Geological Society of America Bulletin* (740 records), *Sedimentary Geology* (684 records), *AAPG Bulletin American Association of Petroleum Geologists* (675 records) and *Marine Geology* (578 records). Analysing these results by countries, it is possible to evidence the following ten principal ones: USA, England, Canada, France, Germany, Italy, Australia, China, Spain and Russia, showing a maximum percentage of 28.3% (USA) and a minimum of 3.59% (Russia). All these data are very helpful to understand the general panorama and state of the art of Stratigraphy and its evolution. If, in a second stage of this analysis, we cross the keywords "Stratigraphy" and "Education" the numbers fully change, decreasing drmatically. Only 15 references/records appear for the same whole period of time, corresponding to the following categories: Geology (6), Geoscience Multidisciplinary (6) and Paleontology (these three categories share 6 records), Geochemistry Geophysics (2 records), Education, Educational Research (1 record), Energy Fuels (1 record), Engineering, Environmental (1 record), Engineering Geological (1 record) and Engineering Petroleum (1 record), being the countries involved: England (6), Australia (3), USA (3), Canada (1), France (1), Germany (1), New Zealand (1), Russia (1), Solomon Islands (1) and South Africa (1). Similar results (only 20 references/records) are obtained after crossing the terms "Stratigraphy" and "Teaching". This evidences that, with more than 24 000 records including "Stratigraphy" and only 15 and 20 incorporating the terms "Stratigraphy" and "Education/Teaching", it is clear that these links need to be strenghten, in order to reflect the real importance of this discipline in the general context of geoeducation.

Geoethics

Geoethics was born in 1991 at the junction of Ethics and Geology (Nemec, 2005), and it has unequivocally shown a spectacular advance in the last two decades linking different disciplines, applying different methodological procedures and technologies, and facing new scientific, social and cultural challenges (Martinez-

Frias *et al*., 2011). However, geoethics is still not very well known. and most of the geoethics-related publications correspond to congress communications (239 between 1992 and 2005) (Nemec, 2007) a monograph (Nikitina, 2012) and a special issue (Peppoloni & Di Capua, 2012), covering a great range of aspects and topics. Geoscientists's professional duties go beyond scientific and technological knowledge and skills. Ethics is part of their (our) professional responsibility. As indicated in the review and analysis regarding geoethics carried out by Martinez-Frias *et al*. (2011), geoscience education and geoethics are two terms which are intrinsically linked. In fact it is not casual that one of the first aspects, related with the first stages of geoethics, were presented in the Kyoto International Geological Congress in the section "New ideas and techniques in geological education" (Nemec, 1992).

Recently, through the IUGS Commission on Geoscience Education, Training and Technology Transfer, the need of this connection was emphasized taking into account a multidisciplinary approach (Martinez-Frias, 2011). The International Association for Geoethics (IAGETH) defines Geoethics as "*an interdisciplinary field between Geosciences and Ethics which involves Earth and Planetary Sciences as well as applied ethics. It deals with the way of human thinking and acting in relation to the significance of the Earth as a system and as a model. Not only geoeducational, scientific, technological, methodological and social-cultural aspects are included (e.g. sustainability, development, geodiversity and geoheritage, prudent consumption of mineral resources, appropriate measures for predictability and mitigation of natural hazards, geosciences communication, museology, etc.), but also the necessity of considering appropriate protocols, scientific integrity issues and a code of good practice, regarding the study of the abiotic world. Studies on planetary geology (sensu lato) and astrobiology also require a geoethical approach*".

A similar searching analysis in the WoS database crossing the keywords "Stratigraphy" and "Ethics" yields only eight references/records, which are restricted to the period 2010-2013. The three main categories are: Energy Fuels, Engineering Petroleum and Geoscience Multidisciplinary.

In short, regarding geoscience education and geoethics, it is essential to note the statement by Bezzi (1999), who refutes the idea that geoscience, in its multiple applications and disciplines, is 'subjective and approximate' and concludes: "*Geologists and earth science educators have the great responsibility to transform geoscience education into a process that must go beyond mere teaching and learning the facts, laws and theories; it must involve understanding the nature of geoscience and its relationships with society*". This approach is also contained in the remarkable NSF- Earth Science Literacy Initiative (NSF-ESLI, 2009). Perhaps, the well known controversial issues concerning the stratigraphic significance of the "Anthropocene" (Zalasiewicz *et al*. 2008; Szerszynski, 2012) could exemplify very well these types of debates, dilemmas and new challenges involving geoeducation and geoethics

Geological Heritage

Geology should be considered in a relationship with nature, culture and history with which it all permanently interact. Humans wish to understand the geographic, natural and socio-economic context in which we develop, therefore a geological approach is necessary. Indeed the history of Human-kind, animals, and of plants is tightly connected with the Earth's history primarily deciphered through stratigraphy. What we call geoheritage are geological features with global, national, or local importance and geological sites that represent processes (magmatic segregation, metamorphism, dissolution, weathering, etc.) or a testimony of the of Earth's history (palaeontology, global tectonics, sea level, stratigraphy). One is dealing with process, the other, the result of geoheritage. Geoheritage related objects from any scale (country side to mineral size) but mainly with mesoscale objects, such as outcrops exposing strata. They offer information or insights into the formation or evolution of the Earth, in the history of science, or can be used for research, references, or educational purposes.

The geological scale is based on the stratotype notion. Since Western Europe was the birthplace of Stratigraphy, it hosts a lot of stratotypic sections. In France, for instance more than forty such sites or sections can be counted. Several of them bear a historical interest but all of them are good candidates to carry a geoheritage notion to a larger public audience. These sites offer the possibility to explain palaeontology, sedimentology, the importance of time in geology, paleogeography, etc., and most of the main concepts used in

geology. This is the reason why The French National Muséum of Natural History launched a collection of books called *Patrimoine géologique, Stratotype* (Geoheritage, Stratotype). The objective was to devote a book to each stratotype. Intended for a wide audience, this collection is delivered with the hope to familiarize the public with these measurements of time so pupils, students, private citizens can gain an awareness of their geoheritage. In these books, the historical and geological aspects are offered but they also underline what are the uses for the rocks of particular ages (to build monuments, to carve sculptures, as an economic resource, i.e.). Included as much as possible is the collections of fossils, of rocks samples, and association with this stage (content, number, museum). This emphasises that geoheritage includes *ex situ* as well as *in situ* objects. At the moment four books (Fig.1) have been published: Lutetian, Albian and Hettangian, and Stampian. Other manuscripts are in the publication process: Barremian, Aquitanian, Aptian, Berriasian, Brioverian, Cenomanian, Danian, Givetian, Sinemurian, Sparnacian , Toarcian and Turonian.

Fig. 1 – Cover of the first books dealing with stratotype: Lutetian (Merle, 2008), Albian (Colleté, 2010), Hettangian (Hanzo, 2012), Stampien (Lozouet, 2012)

References

AULT C.R. (1994) – Research on problem solving: Earth science. *In* Gable D.L. (Ed.), *The handbook of research on science teaching and learning*. Macmillan, New York, 269-283.

BEZZI A. (1999) – What is this thing called geoscience? Epistemological dimensions elicited with the repertory grid and their implications for scientific literacy. *Science Education,* 83, 675–700.

COLLETE C. (Coord.) (2010) – Stratotype Albien. Coll. Patrimoine géologique 2. *Muséum national d'Histoire naturelle*, Paris, *Ed. Biotope*, Mèze & *BRGM,* Orléans, 332 p.

DE WEVER P., EGOROFF G., CORNÉE A., DURANTHON F., WESLEY HILL W. & CABROL, P. – Arnault Lalanne Geoheritage, A national inventory in France. *Geoheritage* (submitted).

DE WEVER P., LE NECHET Y. & CORNEE A. (2006) – Vade-mecum pour l'inventaire national du patrimoine géologique. *Mémoire hors série de la Société Géologique de France* 12, 162 p.

HANZO M. (Coord.) (2012) – Stratotype Hettangien. Coll. Patrimoine géologique 3. *Muséum national d'Histoire naturelle*, Paris, *Ed. Biotope*, Mèze & *BRGM,* Orléans, 316 p.

HERRERA J. S. & RIGGS E. M. (2013) – Identifying Students. Conceptions of Basic Principles in Sequence Stratigraphy. *Journal of Geoscience Education* 61-1, 89-102.

ICS (2010) – Future Directions within the International Commission on Stratigraphy (ICS). *Episodes* 23(4), 283-284.

KING C. (2008) – Geoscience education: an overview. *Studies in Science Education* 44 (2), 187-222.

LOZOUET P. (Coord.) (2012) – Stratotype Stampien. Coll. Patrimoine géologique 4. *Muséum national d'Histoire naturelle*, Paris, *Ed. Biotope*, Mèze & *BRGM,* Orléans, 464 p.

MARTINEZ-FRIAS J. (2011) – IUGS/COGE: The significance of partnership, capacity building and a multidisciplinary approach in geosciences education. *IUGS 50th Anniversary Event* Paris (France), 21 February 2011. http://www.iugscoge.com/pdf_files/IUGS_COGE_50th_Paris_JMFrias.pdf.

MARTINEZ-FRIAS J, GONZÁLEZ J. L. & RULL F. (2011) – Geoethics and Deontology: From fundamentals to applications in Planetary Protection. *Episodes* 34 (4), 257-262.

MARTINEZ-FRIAS J & MOGESSIE A. (2012) – The need for a geoscience education roadmap for Africa. *Episodes* 35 (4), 489-492.

MERLE D. (Coord.) (2008) – Stratotype Lutétien. Coll. Patrimoine géologique 1. *Muséum national d'Histoire naturelle*, Paris, *Ed. Biotope*, Mèze & *BRGM,* Orléans, 288 pages.

MURPHY M. A. & SALVADOR A. (Eds.) (2010) – International Stratigraphic Guide. An abridged version. International Subcommission on Stratigraphic Classification of IUGS International Commission on Stratigraphy *Episodes* 22 (4), 255-271.

NEMEC V. (1992) – Ethical Geology in the Education Process. *29th International Geological Congress, Kyoto, Japan*, Abstract Volume 3/3, section II-24-1, "New ideas and techniques in geological education", Abstract/Paper 06.

NEMEC V. (2005) – Developing Geoethics as a new discipline. *AGID website*. http://www.bgs.ac.uk/agid/Downloads/VN05Geoethics.pdf

NEMEC V. (2007) – To the roots of Geoethics (historical reminiscence). *Hornická Příbram ve vědě a technice.* http://slon.diamo.cz/hpvt/2007/SG/GD1.pdf

NIKITINA N. (2012) – *Geoethics: theory, principles, problems*. Monograph LLC Geoinformmark 2012, 155 p. Moscow. ISBN 978-5-98877-049-7 (*in* Russian).

NSF-ESLI (2009) – http://www.earthscienceliteracy.org/

PEPPOLONI S. E DI CAPUA G. (2012) – Geoethics and geological culture: Reflections from the Geoitalia Conference 2011. *Annals of Geophysics* 55 (3).

SALVADOR A. (1997) – The teaching of stratigraphy (or lack there of) Sedimentary Events, Hydrocarbon Systems. *CSPG-SEPM Joint Convention*. Program with Abstracts, 1997, p. 246.

STOW D. A. V. & MCCALL G. J. H. (Eds.) (1996) – *Geoscience education and training in schools and universities for industry and public awareness*. Balkema, Rotterdam, The Netherlands, 874 p.

SZERSZYNSKI B. (2012) – The end of the end of nature: the Anthropocene and the Fate of the Human. *Oxford Literary Review* 34 (2), 165-184.

ZALASIEWICZ J., WILLIAMS M., SMITH A., BARRY T. L., COE A. E., BOWN P. R., BRENCHLEY P., CANTRILL D., GALE A., GIBBARD P. L., GREGORY F. J, HOUNSLOW M., KERR A., PEARSON P., KNOX R., POWELL P., WATERS C., MARSHALL J., OATES M., RAWSON P. & STONE P. (2008) – Are we now living in the Anthropocene? *GSA Today* 18 (2), 4-8.