An EARTHTIME-EU Science Meeting.

Final Scientific Report

Contents:

1. Summary

A first EARTHTIME-EU scientific meeting was held in the Faculty of Geology of the University of Barcelona, from 23-26 to February 2011. The aim of the meeting was to bring together acknowledged expertise in all subdisciplines of time scale calibration techniques found within the European Earth Science community, with a strong cross-disciplinary character including astronomers, the radioisotopic dating community, and the wider stratigraphic community. During the meeting, scientists discussed on new strategies and state-of-the art techniques in order to link the much improved numerical calibration of the GTS that comes out of the numerical dating to other stratigraphic disciplines (bio-, magneto-, chemo-, and cyclostratigraphy).

The meeting consisted of two full-day scientific sessions (Thursday-Friday) and an optional post-meeting field trip (Saturday), meeting together a total of 42 participants from 13 different EU countries and 34 research institutes and universities. In addition, 4 outstanding experts from the USA were invited to join the meeting, as the EARTHTIME-EU effort is closely linked to the broader international initiative EARTHTIME (www.earth-time.org).

A number of initiatives were raised to increased communication and collaborative work between the different communities involved in the construction of the Geological Time Scale. Within the geochronology community major efforts are being focussed into the intercalibration of the U/Pb and the Ar/Ar geochronometers, and these with the astronomical time. The biostratigraphy community has identified a number of prioritary issues that need to be addressed in the future, such as the standardization of calibration protocols, taxonomy clarity and unambiguous species concepts, and the question of diachrony of bioevents (provincialism, low to high latitude correlations).

2. Scientific content and discussion of the event

The meeting was organized into four sessions:

- ❒ Numerical Dating methods
- ❒ Astrochronology
- ❒ Oceanic Micropaleontology and Biostratigraphy
- ❒ Late Cretaceous-Neogene interbasinal correlations

Each scientific session included a number of key-notes were the state of the art and the scientific forefront of each field was presented. Presentations were followed by discussion on the future actions related to the progress of each field.

Numerical dating methods

Absolute ages based in radioactive decay are the basis for the calibration of the Geological Time Scale. Increasing precision and accuracy of radioisotopic methods is such that a systematic bias is now detected between the most widely used systems (U-Pb and Ar-Ar methods), claiming for an effort of synchronization of geochronometers.

New developments in high-precision U-Pb geochronology were discussed. Among the sources of scatter of the U-Pb method, open system behavior, inheritance, and magma chamber residence time were identified as critical. Recommended protocols to overcome such limitations included: chemical abrasion (CA-TIMS), single crystal and partial crystal analysis, cathodoluminiscence imaging, inter-intra crystal reproducibility and coupled age (CA-TIMS) and geochemical (LA-ICPMS) data. In addition, the implementation of robust error propagation and inter-laboratory calibration experiments were proposed.

The achievement of high-resolution U-Pb ages was highlighted as crucial in order to test orbital cyclicity in the deep time record. Support on the metronomic character of the 405 kyr eccentricity cycle was provided with a study on the late Paleozoic transgressive-regressive sequences of the Donets Basin (USA).

The current status of the Ar-Ar method, widely used in geochronology because of its precission (0.1%), wide temporal range, abundance of K-bearing minerals and low closure temperature, was discussed. An interlaboratory exercise aiming at testing the reproducibility of Ar-Ar results was presented. It consisted in the distribution of one irradiation batch for 20 laboratories and measurement of $^{40}Ar/^{39}Ar$ ratios. The spread of

the results was significantly wider than the 0.1% analytical error, thus indicating that some instrumental issues and/or data reduction protocols may need to be addressed.

In order to avoid dispersion of results related to rock sample heterogeneity, a plan for measurement of gas samples of exactly the same isotope ratios is being developed between the participating labs.

Assessing the accuracy of Ar/Ar methods, the uncertainty resides in the age of the standards and the determination of decay constants. Different studies aiming at calibrating the Fish Canyon Tuff (FCT) standard have yielded a spread of results which is larger than 1%, an error level which is definitely not sufficient to pinpoint, for example, the 400 kyr eccentricity cycle at 60 Ma. A new determination of decay constant is being carried out be means of ingrowth experiments, where a certain amount of ^{40}K is retained for two years, and then the daughter ^{39}Ar is measured.

Intercalibration of the U/Pb and the Ar/Ar geochronometers is of key relevance for the construction of the time scale. In this respect it is important to differentiate mineral age from rock age. Zircon, for example, is a magmatic mineral that growths over 1000 kyr, and only younger zircons may represent the age of eruption. Therefore, some age discrepancies between U/Pb and the Ar/Ar methods may represent true mineral age differences.

Astrochronology

Astronomical (Milankovitch) forcing of Earth's climate is recognized as pacemaker of cyclic sedimentary records, especially from pelagic marine environments. Orbital frequencies are documented in Cenozoic paleoclimate proxies, like stable isotopes, demonstrating the contribution of astronomical forcing to global and regional climate within the $1/10^4$ to $1/10^6$ $year^{-1}$ frequency band. Tuning of sedimentary cyclicity to astronomical solutions of eccentricity, obliquity and precession provides the tool to date sedimentary sequences with unprecedented accuracy, precision and resolution. As a result, astronomical tuning has become the basis for calibrating the Geological Time Scale of the Neogene. Likewise, much effort is being spent in astronomically tuning of Paleogene deep sea records such that these ages will serve in the near future as the

framework for an astronomically-tuned geological time scale of the complete Cenozoic. In this respect, the high Carbonate Compensation Depth that occurred during most of Eocene times has not favored the generation of sedimentary cyclicity in the deep water domain. Cyclostratigraphic studies in shallow water sedimentary environments will be necessary to fill this gap.

A newly released solution of the long term orbital motion of the Earth spanning from 0 to -250 My was presented. This new model is valid over more than 50 Myr in the past with proper phases of the eccentricity variations. Because of to chaotic behavior, the precision of the solution decreases rapidly beyond this time span, and a possible shift of the long-period eccentricity from the 2.4 Ma to 2.0 Ma cycle is suspected to occur at 40 Ma to 60 Ma. It appears that we have thus reached the time where geological data is required to discriminate among planetary orbital solutions beyond 50 Myr. Contributions from cyclostratigraphic studies that constrain the long term orbital solutions are possible, since the 2.4 Ma cycle modulates the 405 and 100 kyr eccentricity cycle, these components being often present in the sedimentary record.

Oceanic Micropaleontology and Biostratigraphy.

Marine biostratigraphy constitutes the core of the Geological Time Scale, providing the tools for the division of the stratigraphic record into time units, or biozones. The stratigraphic usefulness of biostratigraphic zonations relies on its application to long-distance correlations. Thus, assessing the geographic (latitudinal, paleoenvironmental) range of the bioevents used to construct the Geological Time Scale is crucial.

Calibrations of most of the biostratigraphic zonations are from the 1980's, mostly qualitative and of relatively low resolution. In addition, the problem of provincialism of fossil assemblages has not yet sufficiently addressed. Evidences exist today of diachronous species which correspond to biozones. Therefore, ranges still need to be tested repeatedly at different settings, latitudes and basins. Further, a protocol for reporting calibrations is urgently needed that allows full traceability of data.

An even fundamental issue is Taxonomy, the real backbone of biostratigraphic research. In the future much effort must be spend to distinguish between true diachronous events and taxonomy problems. The concepts of species need to avoid ambiguity, favor clarity and be public, possible through a wiki-type database. Reproducibility of results is crucial to ensure reliability of the biostratigraphic tool. In calcareous nannofossil biostratigraphy, where taxonomy follows an unconventional methodology, a special emphasis may be particularly needed.

Late Cretaceous-Neogene interbasinal correlations.

Reconstruction of the evolution of the oceans and continents requires an integrated stratigraphic approach, where marine pelagic facies can be correlated with shallow marine coastal and non-marine facies. To achieve this, a robust intercalibration is needed between open marine (planktonic foraminifera and nannofossils) and shallow marine (larger foraminifera) and continental biostratigraphy. Moreover, correlation between latitudes for particular time intervals is of crucial importance. Paleobiogeographic differentiation and provincialism within both the marine and continental realms add further complexity to this effort.

Neogene Tethys-Paratethys biostratigraphic correlations have failed because of the extreme provincialism of the Paratethys biostratigraphy, based almost exclusively on moluscs. However, magnetostratigraphic studies in the Paretethys realm have revealed best suited to provide a direct calibration against absolute time.

3. Assessment of the results and impact on the future direction of the field.

The continuous progress of scientific research is intimately linked with the technical advances which provided scientist with instruments to measure physical properties with unprecedented precision and accuracy. This has lead to an increasing specialization of many disciplines, with the potential risk of isolation or inability to communicate the advances in one specific field to the rest of the community. Thus, a need for bringing together specialization and collaborative and multidisciplinary work is obvious if the broad perspective, needed to address outstanding fundamental issues, is to be maintained.

Multidisciplanary science meetings are thus most convenient to ensure that scientific knowledge finds the way for dissemination to the broad scientific community and collaborative research is promoted. From the fruitful discussions of the meeting, it was clear that further efforts for transparency, normalization of concepts, full documentation of data, and traceability of scientific results are required in all disciplines. To progress into this, overall agreement was reached on the convenience of a number of follow-up meetings focussed on the following topics:

- Ar/Ar – U/Pb – Astrochronology, "Holmes centenary meeting" (2012-2013) to be held in Sicily. Inter-lab calibration exercises, U/Pb Ar/Ar intercalibration.
- Sharpening the U-Th chronometer. Applications to Quaternary Research and high-precission paleo sea level change. A 2-3 days science meeting at the final stage of an interlaboratory calibration effort.
- Biostratigraphy, taxonomic concepts and calibration of bioevents, to be held in Bulgaria, September-October 2011.

An open call for proposals for science meetings has been already officially announced, and applications will be evaluated at steering committee meeting of early June 2011 in Vienna. Involvement of other disciplines such as Paleomagnetism and Chemostratigraphy in future meetings is encouraged.

It is clear that a fundamental biostratigraphic work is crucial for the achievements of the EARTHTIME network, while funding for biostratigraphy and the number of active biostratigraphers is continuously decreasing. In the mid-term, a proposal for an ITN Network on Biostratigraphy could be prepared and submitted to the ESF.

4. Final Meeting Programme

Wednesday 23 February 2011

18:00 to 21:00 h. Ice breaker at the Hotel Bonanova Park.

Thursday 24

8:45 h. Welcome.

9:00 h. Session 1. Numerical dating methods

Chair: Jan Wijbrans

Key-notes:

9:15 h. Mark Schmitz.
New developments in high-precision U-Pb geochronology and their application to deep time stratigraphy, astrochronology and paleoclimatology.

9:45 h. Klaudia Kuiper
Current status of 40Ar/39Ar geochronology.

10:15 h. Darren Mark.
Syncing Nature's clocks and the harmonization of geological time.

10:30 h. Leah Morgan.
Where Ar we going? The traceable future of $^{40}Ar/^{39}Ar$ geochronology.

10:45 h. Coffee Break

11:00 h. Dan Condon
Assuring precision and accuracy in U-Pb dating (and its application to the stratigraphic record)-I

11:30 h. Urs Schaltegger
Assuring precision and accuracy in U-Pb dating (and its application to the stratigraphic record)-II

12:00 h. Discussion on Session 1
A Proposal of a European platform for U-Th disequilibrium dating (Dan Condon).

12:30 h. Lunch

13:30 h. Session 2. Astrochronology

Chair: Heiko Pälike

Key-notes:

13:45 h Jacques Laskar.
New results from astronomical calculations.

14:15 h Frits Hilgen.
Paleocene ATS, the battle for the age of the K/Pg boundary.

14:45 h Thomas Westerhold.
New results in astrochronology for the Paleogene.

15:15 h Peter Huybers.
Mechanics of Milankovitch forcings.

15:45 h Jaume Dinarès-Turell.
Correlation and astronomical tuning of the Danian-Selandian transition from different basins: from 400-ky tuning to pitfalls at 100 ky eccentricity and precession level.

16.15 h. Tea break.

16.30 h. Discussion on Session 2.

Friday 25

8:45 h. Session 3. Oceanic Micropaleontology and Biostratigraphy.

Chair: Jan Backman

Key-notes:

9:00 h. Bridget Wade.
Overview and introduction to oceanic micropaleontology and biostratigraphy.

9:30 h. Isabella Raffi.
Cenozoic calcareous nannofossils.

10:00 h. Paul Pearson.
Cenozoic planktonic foraminifers.

10:30 h. Coffee Break

10:45 h. Paul Bown.
Mesozoic calcareous nannofossils.

11:15 h. Brian Huber.
Mesozoic planktonic foraminifers.

11:45 h. Discussion on Session 3

12:30 h. Lunch

13:30 h. Session 4. Late Cretaceous-Neogene interbasinal correlations.

Chair: Kristalina Stoykova, Michael Wagreich, Sorin Filipescu

Key-notes:

13:45h. Michael Wagreich.
Tethyan-Boreal correlations in the Late Cretaceous. Still on ammonites and stages?

14:15 h. Eustoquio Molina.
Paleogene stage boundary stratotypes: definition and correlation.

14:45 h. Mathias Harzhauser.
Current status of marine and continental Tethys-Paratethys correlations – a question of scale.

15:15 h. Iuliana Vasiliev.
Chronostratigraphy and correlation of the upper Miocene – lower Pliocene sedimentary records of the Paratethys.

16.00 h. Tea break.

16:15 h. Discussion on Session 4

17.00 h. Plenary discussion.

19.00 h. End of meeting.
21:00 h. Conference Dinner

Saturday 26

8.30 h. **Field trip**.
The marine to continental sedimentary record of the Eastern Ebro Basin (Montserrat and Igualada areas).
Guided by Miguel López-Blanco; Elisenda Costa, Josep Serra-Kiel, Miguel Garcés.

18.00 h. **Return to Hotel**.