



Research Networking Programmes

Science Meeting – Scientific Report

The scientific report (WORD or PDF file - maximum of seven A4 pages) should be submitted online within two months of the event. It will be published on the ESF website.

Proposal Title: “Eustasy and sequence stratigraphy in the Cretaceous Greenhouse”

Application Reference N°: 5448

1) Summary (up to one page)

The meeting was held as a common effort of ESF EARTHTIME-EU and UNESCO IGCP 609 in Bucharest, between the 23rd and 25th of August. A total of 41 participants, mainly specialists for Cretaceous sequence stratigraphy including stratigraphers, scientists from the petroleum industry, and geophysicists, from 14 countries attended the meeting to discuss eustasy and sequence stratigraphy correlations to chronostratigraphy and the numerical time scale for the Cretaceous. The meeting was followed by two IGCP 609 field workshops.

The Bucharest meeting addressed extend, correlation, timing, causes and consequences of significant short-term, i.e. kyr to 100s of kyr to a few million year, sea-level changes during the last major greenhouse episode of the Earth system, the Cretaceous. Processes and triggering mechanisms for these short-term sea-level fluctuations during greenhouse times are highly controversial. Global eustasy, involves processes like brief glacial episodes (glacio-eustasy) for which evidence was given, at least for the Early Cretaceous and the late Late Cretaceous. An alternative or additional process was suggested during the meeting, i.e. the storage and release of groundwater (limno-eustasy or aquifer-eustasy).

Several critical time intervals of the Cretaceous and single sea-level cycles were discussed in detail, and correlated to the new emerging time-scale of the Cretaceous, especially in relation to sequence stratigraphy (including unpublished industry data) and astronomical cycles. Critical time slices, i.e. the Aptian, the Cenomanian-Turonian, and the Campanian-Maastrichtian, were discussed in detail. Correlations from Arabia to Europe indicate isochronous and orbitally controlled sea-level fluctuations of various magnitudes and durations during the mid-Cretaceous hothouse phase.

Sequence stratigraphy was put into a numerical time frame for the Cretaceous using selected case studies, and integrated stratigraphic records using sequence stratigraphy (and eustatic cycles) biostratigraphy, chemostratigraphy (i.e. stable isotopes), magnetostratigraphy, and astronomical calibration. The main mechanisms for global and regional sea-level changes were quantified. and regional (tectonically induced) versus global mechanisms for sea-level change were discussed as well as problems that involve inconsistencies in taxonomic concepts, rare occurrence or selective preservation of key taxa or their true diachroneity in the sedimentary record. The industrial perspective was brought in using eustatic models as precise temporal frameworks for the correlation, prediction and mapping of facies in the exploration environment.. Various proxy interpretations for sea-level reconstructions in the Cretaceous were challenged.

Orbital forcing via climate is identified as the main driver of sea-level cycles also during greenhouse times.

2) Description of the scientific content of and discussions at the event (up to four pages)

The location of the meeting was the University House, where both the Oral Session (with 26 presentations) and the Poster Session (including a short presentation of each of the 15 posters) took place. The meeting was followed by two geological field trips sponsored by IGCP: the first one (between the 26th-28th of August) was devoted to the examination of Cretaceous successions in the Eastern Carpathians, and the second one (between 29th-31st of August) was focused on Cretaceous marine and continental deposits of the Southern Carpathians. Participants met at the first day of the meeting, after travelling to Bucharest, at a visit of the Geological Museum of the National Geological Institute of Romania, followed by an Ice Breaker at the National Institute of Marine Geology and Geo-ecology Institute.

The first day of presentation started with three key notes; the speakers discussed the solid earth's influence of sea-level, the inherited landscapes linked to sea-level repeated changes, as well the importance of a deep knowledge of eustatic changes for geoscientists working in the oil industries. In the afternoon of the first day presentation, several key notes on eustasy, cycles and geological time scales have been presented and discussed. During the second day of the meeting, the presentations focussed on various aspects related to the stratigraphy, events, biota, and sea-level changes of the Cretaceous times. The oral presentations have been followed by the discussion poster session, where the scientists, mainly young researchers and students, presented new data on the Cretaceous Greenhouse world. Discussion groups on various topics met during these break-out times. The meeting ended with discussion in a Plenary Session, where the conveners summarized the main scientific directions and outcomes, and discussed cooperations. Future directions to be developed in the field of sequence stratigraphy and greenhouse eustasy have been also pointed out.

In general, the scientific content of the workshop was focused on sea-level changes in a greenhouse world such as the Cretaceous. The recent rise in sea-level in response to increasing levels of atmospheric greenhouse gases and the associated global warming is a primary concern for society. To predict future sea levels a better understanding of the record of past sea-level changes is mandatory. In contrast to glacial eustasy controlled mainly by waxing and waning of continental ice sheets, short-time sea-level changes during major greenhouse episodes of the Earth history are still poorly understood. The global versus regional correlation as well as the timing, the causes, and the consequences of these sea-level changes have been discussed during the workshop. In detail, major topics include reviews of proxies used for identifying sea-level changes in marine sediments, including pelagic and hemipelagic deposits, but also turbidite ones. Case studies and new data in this topical frame have been presented from the Arabian Plate (Florian Maurer, Mike Simmons), Austria (Michael Wagreich, Benjamin Sames and Erik Wolfgring), Bulgaria (Jacek Grabowski, Polina Pavlishina and Kristalina Stoykova), China (Chen Xi and Xiaoqiao Wan), Jordan (Jens Wendler), Germany (Markus Wilmsen), Poland (Ewa Malata), Romania (Jaume Gallemi, Mihaela Melinte-Dobrinescu, Cornel Olariu, Silviu Rădan, Relu Roban and Dorina Țambrea), Russian Federation (Ludmila Kopaevich and Svetlana Zorina), Tanzania (Ines Wendler), Turkey (Okan Tüysüz and Ismail Yilmaz), Spain (Florentin Maurrasse) and USA (Ronald Steel).

Bilal Haq has highlighted various solid earth processes and their implications for the stratigraphic record, and especially as it is preserved on continental margins. The speaker took into consideration recent worldwide syntheses of stratigraphic data that led to an updated eustatic history of Cretaceous times, and gave global measures for sea-level change.

A new astronomical tuning, based on the investigation of some Upper Cretaceous Italian sections has been presented by Mario Sprovieri, who proposed, based on long-term $\delta^{13}\text{C}$ eccentricity cycles tuned, stable 405 kyr cycles of the La2010 astronomical solution. The speaker has hypothesized that ~8.0, 4.7, 3.4 and ~2.4 Myr cycles modulate the entire $\delta^{13}\text{C}$ record and offer the opportunity to extend their detection from the Cenozoic to ~100 Ma; these represent primary and stable long-term oscillation modes of Earth's climate-ocean system.

Mike Simmons discussed Cretaceous eustasy from an industrial perspective. In his presentation he has shown how the eustatic control has been utilised in the quest to find more oil and gas with examples from a global perspective, based on an enormous global database.

Florian Maurer focussed on high amplitude Cretaceous sea-level fluctuations recorded in the carbonate systems of the E Arabian Plate. He concluded that the construction of similarly complete and well documented transects along the margins of the NeoTethys Ocean would be an important step towards establishing a better insight in the nature (rate and amplitude) of global sea-level fluctuations and their effect on sedimentation patterns.

Dynamic polar climate in an Early Cretaceous greenhouse world have been introduced by Gregory Price. Data proceeding from isotope analysis of many Lower Cretaceous sediments world-wide distributed are consistent with intervals when polar ice was unlikely, but also when polar ice was plausible supporting the view of generally warm but dynamic polar climates. Combined oxygen and clumped isotope data also allow for the assessment of the isotopic composition of seawater.

Svetlana Zorina's presentation focussed on modelling of accommodation and siliclastic sedimentation mechanisms in platform sedimentary basins. In her presentation, she took into consideration the diversity of scenarios leading to the formation of progradational and retrogradational parasequence sets. Thus, the models proposed in this communication to supplement the theoretical basis of sequence stratigraphy offer the opportunity to widen the spectrum of probable scenarios and consequences of interaction between global eustasy, tectonic vertical movements, and the depositional gradient.

Markus Wilmsen analysed correlations between sedimentary basins in Europe, N Africa and Middle East, emphasizing the implications for amplitudes, rates and periodicities of Cretaceous sea-level changes. Cyclostratigraphic analyses of successions deposited in deep intra-shelf basins of N Germany have indicated that mid-Cretaceous, i.e., late Early Cenomanian to Middle Turonian depositional sequences DS Ce 3 to DS Tu 3 contain an identical number of ca. 60 precession couplets (~20 kyr) bundled into twelve short- (~100 kyr) and three long-eccentricity cycles (~400 kyr). This finding supports the orbital control on sea level and the long-term amplitude modulation cycles of the Milankovitch oscillations.

Intersection of Earth's solid, liquid, and gaseous components, linked to sea level fluctuations have been pointed out by Clint Conrad. On timescales ranging from decades to millennia, the solid earth deforms both elastically and viscously in response to redistributions of hydrologic loads on the Earth's surface. Important basic concepts and quantitative implications for sea level have been stated.

Ismail Yilmaz discussed records of Late Cretaceous tectonically enhanced sequence boundaries and short-term sea-level changes, giving a suggestive example from the Arabian Plate of SE Turkey. Tectono-sea level changes can be observed in large-scale and with relatively bigger time gap on the Arabian plate, however small-scale cycles can represent climate/oceanographic/tectono-oceanographic changes, and can be correlated globally (i.e. in the Aptian)

Temporal variations of characteristic microfacies, based on detailed geochemical investigations allowed to Florentin Maurrasse to reveal various degrees of recurring dysoxic to suboxic conditions throughout the Early Cretaceous, i.e. Barremian-Aptian interval, of Organya Basin of N Spain. He concluded that continuous high accumulation rate is compatible with deepening phase that started in the late Barremian consistent with regional tectonism of a pull-apart basin that developed when Iberia rifted and rotated counterclockwise away from Europe.

Michael Wagreich introduced the term of limno-eustasy that describes a mechanism for short-term eustatic sea-level changes during the Cretaceous Greenhouse climate. The limno-eustatic hypothesis may be testable given high-resolution stratigraphic correlations between marine and continental lake archives during supposed ice-free periods of Earth history, as for the Cretaceous times. Examples from several Chinese basins have been presented. During the workshop, some main questions and problems were discussed, such as if the Cretaceous eustatic signal can be defined quantitatively, and if so, what is the main driving process, and what positive and negative feedback mechanisms apply. Bilal Haq, Michael Wagreich, Ines Wendler, Gregory Price and Jens Wendler reminded that this is not so straight-forward as we might like, especially when it comes to definitive Cretaceous glacio-eustasy, although the circumstantial evidence is getting stronger that during Early Cretaceous and late Late Cretaceous, sea-level changes were triggered by cold snaps. During the mid-Cretaceous hothouse climate phase of extreme greenhouse conditions, an additional and/or alternative process may be based on wet-dry climate cycles, and the fill and release of groundwater from continental aquifers.

3) Assessment of the results and impact of the event on the future directions of the field (up to two pages)

A first conclusion of the meeting was related to the importance of using multiple parameters in characterizing a geological event such as a sea-level cycle. Hence, a real advance could be realized in deciphering the palaeoenvironmental changes of the Cretaceous times, in particular of the mid-Cretaceous interval, described as 'the Cretaceous Greenhouse', by using radiometric dates and numerical calibration of bio-zonations (based on the investigation of various groups of organisms), carbon and strontium isotope curves, paleomagnetic reversals, as well as astronomically calibrated time scales.

Another important conclusion is that the regional and local sea-level record need to be compared to tectonic forcing and the issue of solid-earth influences on eustasy at various temporal scales will be reviewed. A very useful tool to decipher Cretaceous environmental changes, including sea-level fluctuation is the comparison between the global eustatic curve (e.g., published by Haq, 2014) with regional eustatic curves, from regions characterized during the Cretaceous by different tectonic and paleogeographic settings, i.e., shallow marine versus deep marine, and on a numerical precise time-scale as given by EARTHTIME-EU. First results of precise dating of single sea-level cycles, e.g. in the Aptian or Turonian, have been discussed, and will allow more precise global correlations and quantifications.

A future direction in the field that was agreed on by the workshop scientists is to quantitatively assess the effect of alternative processes such as water volumes that are bound to groundwater and lake storage on sea-level fluctuations and cycles during major greenhouse phases of Earth history, including the Cretaceous times. This kind of investigation, included under the new term of 'limno-eustasy', may further differentiate the dimension of purely ice-driven glacio-eustatic processes. As vast regions of the Earth exposed continental Cretaceous strata, in addition to the marine ones, it is necessary to precisely correlate these different non-marine facies by proxies which could be successfully used in the future in both environmental settings. A good example is the completion of the Geological Time Scale of the continental and marine Cretaceous of China, presented during the meeting by Xiaojiao Wan.

An important future issue, in order to demonstrate that eustasy can indeed be validated and the driving mechanisms for its occurrence explored, is to accommodate regional and global scales. As discussed by Mike Simmons from an industrial perspective, the real value of a eustatic model will be to provide a precise temporal framework for the correlation, prediction and mapping of facies - facies that can be related understanding the risk on the presence of source rocks, reservoir rocks and seals.

As significant perspectives in developing the fields of eustasy and sequence stratigraphy have been highlighted, the meeting participants decided to propose a Special Volume to include the

presented papers in the Earthtime-EU Sequence Stratigraphy Workshop of Bucharest, August 2014. A preliminary title of this volume, which will be proposed to Palaeogeography, Palaeoclimatology, Palaeoenvironment (Elsevier) or to Proceedings of the Geologist's Association (Elsevier) is "Advances and Perspectives in understanding Cretaceous sea-level change", having as proposed editors: Michael Wagreich, Mihaela C. Melinte-Dobrinescu, Benjamin Sames, Ismail Ö. Yilmaz and Bilal Haq. So far, 13 papers are proposed for this proceedings volume, including basic reviews of concepts and processes of Cretaceous sea-level changes and sequence stratigraphy, as well as precise correlations of the eustatic record to the numerical time scale.

4) Annexes 4a) and 4b): Programme of the meeting and full list of speakers and participants

Annex 4a: Programme of the meeting

Saturday, the 23rd of August

18.00-19.00 *Visit of the Geological Museum*

19.00 – ... *Ice breaker party at GeoEcoMar*

Sunday, August 24, 2014

8:30-8:45 *Welcome*

8:45-9:10 Michael Wagreich

INTERNATIONAL GEOSCIENCE PROGRAM PROJECT IGCP 609 AND ESF RESEARCH NETWORKING PROGRAM EARTHTIME-EU: RESEARCH INTO THE CRETACEOUS WORLD

Invited overview key notes

9:10-10:00 Clinton Conrad

THE SOLID EARTH'S INFLUENCE ON SEA LEVEL

10:00-10:30 *Coffee/Tea Break*

10:30-11:20 Bilal Haq

INHERITED LANDSCAPES AND SEA-LEVEL CHANGE: AS EXEMPLIFIED BY CRETACEOUS

11:20-12:10 Mike Simmons

CRETACEOUS EUSTASY: INDUSTRIAL PERSPECTIVES

12:10-13:30 *Lunch Break*

Key notes: Eustasy, Cycles and Time Scales

13:30-14:00 Mario Sprovieri

ASTRONOMICAL TUNING OF THE UPPER ALBIAN-LOWER CAMPANIAN: FROM SHORT TO VERY LONG-TERM ORBITAL CYCLES

14:00-14:30 Ismail Yilmaz

EUSTATIC AND TECTONIC CONTROLS IN RECORDS OF CRETACEOUS SEA-LEVEL CHANGES ON THE CENTRAL TAURIDE AND PONTIDE PLATFORMS

14:30-15:00 Florian Maurer

HIGH AMPLITUDE CRETACEOUS SEA LEVEL FLUCTUATIONS RECORDED IN THE CARBONATE SYSTEMS OF THE EASTERN ARABIAN PLATE

15:00-15:30 Markus Wilmsen

SEQUENCE STRATIGRAPHIC CORRELATIONS BETWEEN SEDIMENTARY BASINS IN EUROPE, NORTHERN AFRICA AND THE MIDDLE EAST: IMPLICATIONS FOR AMPLITUDES, RATES AND PERIODICITIES OF EARLY LATE CRETACEOUS SEA-LEVEL CHANGES

15:30-16:00 *Coffee/Tea break*

16:00-16:20 Gregory Price

DYNAMIC POLAR CLIMATES IN AN EARLY CRETACEOUS GREENHOUSE WORLD

16:20-16:40 Jens Wendler

CHALLENGES IN RECONSTRUCTION AND GLOBAL CORRELATION OF CRETACEOUS SEA-LEVEL FLUCTUATIONS

16:40-17:00 Michael Wagreich

LIMNO-EUSTASY – A MECHANISM FOR SHORT-TERM EUSTATIC SEA-LEVEL CHANGES DURING THE CRETACEOUS GREENHOUSE CLIMATE

17:00-17.20 Xiumian HU

TECTONIC AND CLIMATIC CONTROL ON CRETACEOUS-PALEOGENE SEA LEVEL CHANGES IN NORTHERN INDIAN MARGIN (TIBETAN TETHYS HIMALAYA)

17:20-17:40 Svetlana Zorina
MODELLING OF ACCOMMODATION AND SILICICLASTIC SEDIMENTATION MECHANISMS IN
PLATFORMAL SEDIMENTARY BASINS
17:40-18:00 Xiaoqiao Wan
EARTHTIME CHINA: INTEGRATED CRETACEOUS STRATIGRAPHIC TIME SCALE OF CHINA

Monday August 25, 2014

8:20-10:30 Stratigraphy, Events, Biota, and Sea-level changes

EARLY CRETACEOUS

8:20-8:40 Jacek Grabowski
MAGNETOSTRATIGRAPHY, MAGNETIC SUSCEPTIBILITY AND CALPIONELLID STRATIGRAPHY OF
THE UPPER BERRIASIAN IN THE WEST BALKAN MTS., BULGARIA (BARLYA SECTION)

8:40-9:00 Cornel Olariu
THE IMPORTANCE OF FRACTURED OLISTOLITHS AND SHELF-GRAVEL SORTING FOR THE
CONSTRUCTION OF A TECTONICALLY-CONTROLLED MARGIN: CASE STUDY THE ALBIAN
BUCEGI CONGLOMERATES, EASTERN CARPATHIANS, ROMANIA.

9:00-9:20 Florentin Maurrasse
HIGH-RESOLUTION CHEMOSTRATIGRAPHY AND FACIES ANALYSIS OF AN EARLY CRETACEOUS
EXPANDED SECTION OF THE ORGANYÅ BASIN: IMPLICATIONS FOR BARREMIAN-APTIAN
GLOBAL $\delta^{13}C$ CORRELATION AND SEA LEVEL CHANGES

MID-CRETACEOUS

9:20-9:40 Relu-Dumitru Roban
SHORT ORBITAL CYCLES IN THE MID CRETACEOUS TIMES: AN EXAMPLE FROM THE EASTERN
CARPATHIANS (ROMANIA)

9:40-10:00 Polina Pavlishina
PALYNOLOGY OF THE ALBIAN – CENOMANIAN BOUNDARY INTERVAL IN A PART OF NORTH
BULGARIA

10:00-10:20 Mihaela Melinte-Dobrinescu
CRETACEOUS SEA-LEVEL CHANGES IN THE SOUTHERN CARPATHIANS (HATEG BASIN,
ROMANIA)

10:20-10:40 Okan Tüysüz
CENOMANIAN-TURONIAN PALAEOGEOGRAPHY OF THE PONTIDES, NORTHERN TURKEY

10:40-11:00 Coffee/Tea Break

11:00-11:40 Ron Steel
IMPORTANCE OF TIDAL DEPOSITS IN THE CAMPANIAN WESTERN INTERIOR SEAWAY, USA

11:40-12:00 Jaume Gallemí
THE CRETACEOUS ECHINOIDS OF ORMENIŞ (BRAŞOV, PERŞANI MOUNTAINS, EASTERN
CARPATHIANS): SYSTEMATICS, BIOSTRATIGRAPHY AND PALAEOBIOGEOGRAPHIC
SIGNIFICANCE

LATE CRETACEOUS

12:00-12:20 Ismail Yılmaz
RECORDS OF LATE CRETACEOUS TECTONICALLY ENHANCED SEQUENCE BOUNDARIES AND
SHORT-TERM SEA LEVEL CHANGES, SE TURKEY, ARABIAN PLATFORM

12:20-12:40 Corneliu Dinu
BASIN SUBSIDENCE AND ITS IMPLICATION TO SEDIMENTARY SEQUENCES GENERATION,
CENTRAL ROMANIAN BLACK SEA OFFSHORE

12:40-13:40 Lunch Break

13:40-14:00 Erik Wolfgring
PALAEOENVIRONMENT AND BIOSTRATIGRAPHY OF POSTALM-SECTION, NORTHERN
CALCAREOUS ALPS (AUSTRIA)

14:00-14:20 Ines Wendler CHALLENGES IN RECONSTRUCTION AND GLOBAL CORRELATION OF
CRETACEOUS SEA-LEVEL FLUCTUATIONS

14:20-14:40 Coffee/Tea Break

14:40-16:00 POSTER SESSION

16:00-18:30 Plenary Session Discussion, EARTHTIME-EU and Sequence Stratigraphy

19.00 – Gala Dinner

Annex 4b: Full list of speakers and participants

CONVENERS

Mihaela C. Melinte-Dobrinescu	Bucharest, (RO)
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Relu-Dumitru Roban	Bucharest, (RO)
Benjamin Sames	Vienna, (AT)
Michael Wagreich	Vienna, (AT)
Ismail Omer Yilmaz	Ankara, (TR)

SPEAKERS

Conrad Clint	Honolulu, (US)
Bilal Haq	Washington DC, (US)
Gregory Price	Plymouth, (UK)
Mike Simmons	Oxfordshire, (UK)
Mario Sprovieri	Fraz. Campobello di Mazara, Tp, (IT)
Markus Wilmsen	Dresden, (DE)

PARTICIPANTS

Iuliana Cojocariu	Bucharest, (RO)
Corneliu Dinu	Bucharest, (RO)
Jaume Gallemí	Barcelona, (ES)
Jacek Grabowski	Warsaw, (PL)
Dan Grigorescu	Bucharest, (RO)
Xiumian Hu	Nanjing, (CN)
Dan Jipa	Bucharest, (RO)
Ludmila Kopaevich	Moscow, (RU)
Ewa Malata	Krakow, (PL)
Florian Maurer	Copenhagen , (DK)
Florentin Maurrasse	Miami, (US)
Jozef Michalik	Bratislava, (SK)
Ion Munteanu	Madrid, (ES)
Birgit Niebuhr	Dresden, (DE)
Cornel Olariu	Austin, Texas, (US)
Polina Pavlishina	Sofia, (BG)
Adrian Popa	Bucharest, (RO)
Silviu Radan	Bucharest, (RO)
Jander Socorro	Miami, (US)
Ronald Steel	Austin, (US)
Marius Stoica	Bucharest, (RO)
Kristalina Stoykova	Sofia, (BG)
Dorina Tambrea	Bucharest, (RO)
Okan Tuysuz	Istanbul, (TR)
Xiaoqiao Wan	Beijing, (CN)
Ines Wendler	Bremen, (DE)
Jens Wendler	Bremen, (DE)
Erik Wolfgring	Vienna, (AT)
Chen Xi	Beijing, (CN)
Svetlana Zorina	Kazan, (RU)