International Workshop on Climate and Environmental Evolution in the Mesozoic Greenhouse World

and

3rd IGCP 609 Workshop on Cretaceous Sea-Level Change

ABSTRACT VOLUME

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"Climate-environmental deteriorations during greenhouse phases: Causes and consequences of short-term Cretaceous sea-level changes"

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[1] CURRENT STATUS OF IGCP 608 "ASIA-PACIFIC CRETACEOUS ECOSYSTEMS" AND THE FURTHER COOPERATION WITH IGCP 609

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The IGCP 608 project (2013-2017), a sister project of IGCP 609 is briefly reviewed in terms of the current status of three years activities and the further cooperation with IGCP 609. The project is entitled "Cretaceous Ecosystems and Their Responses to Paleoenvironmental Changes in Asia and the Western Pacific", and shortly "Asia-Pacific Cretaceous Ecosystems". In this project, the spatio-temporal paleoenvironmental and paleoecosystem changes during the Cretaceous in the South to East Asia and Western Pacific region have been delineated on the basis of paleoproxy data and a diversified fossil record from wider areas and different locations.

This project comprises two groups of major topics to be discussed: 1) variations of terrestrial and marine environments, and 2) evolution of terrestrial and marine ecosystems. The terrestrial strata widely distributed in South and East Asia yield abundant indicators, both biotic and lithologic, that are essential for deciphering how the ecosystems were affected by paleoclimatic and paleoenvironmental changes. Marine sediment records in the Western Pacific rim and Eastern Tethys region provide several significant information on the marine paleoenvironmental changes, including paleooceanographic conditions, temperature fluctuations, latitudinal temperature gradients, OAEs, ORBs, ocean acidification, etc. We look forward to obtain important results such as the establishment of close links between atmospheric CO2 levels, global temperature and precipitation, climatic zonation patterns, paleo-weathering conditions and orbital-scale paleoclimatic fluctuations.

Now we have over two hundred scientists from 14 Asian countries and half a dozen countries outside Asia, joining our mailing list. They are tackling a widely various aspects of Cretaceous ecosystems according to their specialties and period studied, following the preceding successful East Asian Cretaceous IGCPs (IGCP350, 434 and 507). Therefore, our Asian Cretaceous geoscience community has been continued over 20 years since 1993, for promoting international communication and collaboration in the various ways among the Asian countries, including some countries outside Asia.

The first international meeting was held at Birbal Sahni Institute of Palaeobotany (BSIP), Lucknow, India, from December 20-22, 2013. A total of 45 scientists and students gathered from five countries. The current knowledge of Cretaceous geology and paleontology in Asia, especially south Asia was reviewed in the symposium and the subsequent four-days field excursion to Cretaceous Bagh-Lameta sequences in the western part of the Narmada basin of Central and Western India.

The second symposium (September 4-10, 2014, Waseda University, Tokyo, Japan) and post-symposium field trip brought together more than 92 Earth Scientists from 13 countries, including graduate students and representatives of petroleum and resources companies. Session themes include OAEs, land-ocean linkage, Asian geoparks highlighting Cretaceous, etc. In a post-symposium four-day field excursion, we focused the forearc basin siliciclastic successions exposed along the Pacific coast 100 to 250 km east to northeast from Tokyo, Central Honshu Island.

The third year activity of IGCP608 is in progress as a joint meeting with MTE-12 (The 12th Symposium on Mesozoic Terrestrial Ecosystems) at Liaoning Mansion Hotel, Shenyang, Liaoning Province, China, during 16-18 August 2015. The two-days field excursion will visit and observe the Early Cretaceous “Jehol Biota” in Beipiao City area and the Jurassic “Yanliao Biota” in Jianchang County area, Western Liaoning.

Several our scientific results during 2013 and 2014 will be published in the thematic section of “*Island Arc*”, one of Wiley online journals, as their editorial processes are in progress.

Further cooperation and communication will be necessary for the next 35th IGC and two remaining year’s activities of both projects.

[2] THE NEW NANNOFOSSILS OF JURASSIC BLACK SHALES FROM THE QIANGTANGBASIN, NORTHERN TIBET

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The marine Jurassic sedimentary strata of the Qiangtang Basin, northern Tibet are well known for their organic carbon-rich shales, abundant fossils and the most complete and extensive sections, especially as regards Middle to Upper Jurassic strata. However, understanding of their stratigraphic age, depositional environment, and prevailing climatic conditions is incomplete. The lack of well-preserved ammonites makes recognition of key Jurassic stages particularly difficult. However, the recent discovery of coccoliths in the section described herein has proven particularly useful as a biostratigraphic aid.

Although no new ammonites were discovered (only bivalves), a number of samples yielded age-significant coccoliths. Biostratigraphic interpretations follow the zonal schemes of Bown and Cooper (1998) and Mattioli and Erba (1999). Thirty-five taxa were identified, including various morphotypes of *Watznaueria britannica* and differently sized *W. manivitiae*. In general, nannofossils are very poorly to quite moderately preserved in the two studied sections (Biluo Co and Amdo 114 station), although assemblages from the Biluo Co section are overall slightly better preserved. Etching is common but overgrown was also observed. The assemblages are dominated by species of the Watznaueriaceae, as it is the case for most of the known sections of Middle Jurassic. In spite of the generally poor preservation of coccoliths, entire coccosphaeres were observed both in optical microscope and SEM. Some enigmatic specimens of *Rucinolithus* and *Pseudoconus enigma* were recorded. Interestingly, these taxa are reported by Tiraboschi and Erba (2010) from the Bathonian of SE France. Additionally, the abundance of *W. barnesiae* and the presence of *Cyclagelosphaera wiedmannii* marks the latest Bathonian or earliest Callovian. This age is also confirmed by the occurrence of *Biscutum dorsetensis*, *Ansulasphaera helvetica*, *Octopodorhabdus decussatus*, *Stephanolithion hexum* (all appearing in the Late Bathonian), so that attribution of the samples to the Bajocian, Bathonian and possibly Callovian stages of the Middle Jurassic is secure.

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[3] NEW STUDIES ON THE CRETACEOUS OCEANIC ANOXIC EVENTS IN THE TINGRI AREA, SOUTHERN TIBET

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Although the concept of the oceanic anoxic event (OAE) was introduced nearly 40 years ago, the coeval deposits in southern Tibet and their implications for paleoenvironment were firstly studied ~25 years later (e.g. Wang et al., 2001). In the last decade, the researches of OAEs in southern Tibet mainly focused on the OAE2 (Cenomanian-Turonian boundary Event). The biostratigraphy, carbon isotope curve and redox condition of OAE2 in southern Tibet were well studied (Wang et al., 2001; Li et al., 2006; Wendler et al., 2009; Bomou et al., 2012). Other OAEs, e.g. OAE1a, 1b, 1c and 1d, have not been reported yet in the area. Here we present the initial results of study on the Cretaceous OAEs including the identification of the OAE1a and 1d, and the new findings on the OAE2.

In the lower Aptian black shale/mudstone succession of Tingri area, we chanced upon a diverse and moderately to well preserved ammonite fauna (> 10 species) at four fossiliferous levels. The presence of two ammonite zones, namely D. forbesi and D. deshayesi zones, is paleontologically proved. A distinct δ^{13}Corg negative excursion of ~3‰ is a few meters below the first occurrence of *Deshayesites* cf. *gracilis* Casey, 1964, just around the boundary between D. forbesi and D. deshayesi zones . This event is followed by a ~1.5‰ positive excursion. Upward, theδ^{13}Corg values stay stable in a black shale interval. According to the ammonite biozones, we correlate the δ^{13}Corg curve segments respectively to C3, C4 and C5 ones, recorded in the marine successions of other continents.

Furthermore, we firstly established the calcareous nannoplankton zones and subzones for the late Albian to early Turonian interval in the Tingri area. A slight δ^{13}Ccarb positive excursion of ~0.3% has been identified in the nannofossil zone UC0. Based on the biostratigraphy and δ^{13}Ccarb curve, we suggest that this event is probably the regional expression of OAE1d. Although the δ^{13}Ccarb positive excursion could be correlated with the OAE1d in other continents, redox sensitive element Mn indicates an oxic condition prevailing throughout the Albian/Cenomanian boundary interval.

Carbon isotope values of organic matter and bulk rock were measured for the uppermost Cenomanian-lowermost Turonian carbonate sediments in the UpperCretaceous reference section of the studied area, Gongzha section.The δ^{13}Corg and δ^{13}Ccarb curves include the main features of the classic positive $\delta^{13}C$ excursion seen in other parts of the world during the OAE2. The differences of $\delta^{13}Corg$ and $\delta^{13}Ccarb$ ($\Delta^{13}C$) values reveal that the pCO_2 fluctuated significantly throughout the event. The $\Delta^{13}C$ curve of OAE2 in Gongzha section can be well correlated to the weathering intensity changes revealed by Li isotope in English chalk in the same interval (von Strandmann et al., 2013).

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[4] CRETACEOUS SEA-LEVEL FLUCTUATIONS – EXPLORING THE EFFECTS OF PHYSICAL AND BIOGEOCHEMICAL FORCING

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The question whether large scale glaciations on Antarctica were possible in a late Mesozoic greenhouse climate such as the Late Cretaceous is an intriguing one. The most recent years have provided an increasing number of studies investigating the growth and decay of paleo-continental ice sheets on Antarctica possibly large enough to affect sea level. Since the outcome of these studies doesn't provide a basis for a conclusive decision we have performed a number of model runs using an Atmospheric General Circulation Model (AGCM) to test whether large volumes of snow might have accumulated even under Late Cretaceous greenhouse conditions. By varying orbital parameters as well as topography, and atmospheric CO_2 concentrations our models indicate the possibility of an Antarctic ice shield build-up large enough to drive sea level fluctuations on the order of tens of meters within ~20,000 years. This is supported under the assumption of pCO_2 levels <800 ppm, low insolation, and elevated topography. The growth of a major Antarctic ice sheet would be possible on reasonable time scales. To accumulate about half the present day snow/ice volume thatwould be required to explain the documented shifts in oxygen isotopes our model results suggest a time span between 20,000 and 80,000 years for these ice volumes to accumulate.

Recently, Wallmann (2014) has shown that a simple biogeochemical box model is capable to develop stable self-sustained 100 kyr oscillations. These free oscillations feature pCO_2 minima and maxima consistent with the ice-core record when vertical mixing in the ocean is allowed to vary in response to a pCO_2-controlled temperature change. A stable 100-kyr cycle with a rapid transition from glacial to interglacial conditions is obtained when additional non-linear equations are applied to calculate deep ocean mixing, iron fertilization and the depth of organic matter degradation as function of pCO_2-controlled surface temperature. The oscillations are induced and maintained by sea-level change generating persistent imbalances in the marine carbon and phosphorus budgets.

Similar oscillations can be generated using a Cretaceous biogeochemical box model with eccentricity-related changes in global mean temperature. This mechanism further indicates the possibility of ice-sheet driven sea-level fluctuations during the warm climates of the Cretaceous.

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[5] MID-LATITUDE TERRESTRIAL CLIMATE OF EAST ASIA LINKED TO GLOBAL CLIMATE IN THE LATE CRETACEOUS: EVIDENCES FROM STABLE ISOTOPES AND CLAY MINERALS OF THE SCIENTIFIC CORE IN THE SONGLIAO BASIN

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The Late Cretaceous (late Campanian to Maastrichtian) was characterized by a variable greenhouse climate, with evidence for cooling and/or glaciation and warming events. Most of these climatic signals are derived from marine records, and knowledge of the terrestrial climate, especially in the mid-latitudes, is limited due to fragmentary geological records on continents. Here we report mid-latitude terrestrial stable oxygen and carbon isotopic and clay mineralogical data in the nearly continuous Late Cretaceous age SK-1 core drilled in the Songliao Basin, northeastern China. Our data indicate a punctuated, mid-latitude terrestrial climate in the Late Cretaceous. A large negative $\delta^{18}O$ excursion (~3‰) documented by the SK-1 pedogenic carbonate nodule in the early Maastrichtian (~70Ma) is interpreted to be the result of decreasing temperature and/or strengthened westerlies during global cooling. At the same time, increases in illite content and the quartz/clay ratio, and decreases in illite chemistry index indicate increasing physical weathering and therefore a more arid climate. The negative $\delta^{13}C$ isotopic excursion at ca. 66Ma and 69Ma are modeled as higher primary productivity caused by increasing temperature and precipitation in response to a warming climate. Clay mineralogical proxies also indicate increasing chemical weathering and a more humid climate. Our results demonstrate the sensitivity of mid-latitude terrestrial climate in a greenhouse world.

[6] PALEOENVIRONMENTS AT PEAK OF OCEANIC ANOXIC EVENT 1A (OAE-1A) AT THE MADOTZ SECTION (NAVARRA, SPAIN): A SEDIMENTOLOGICAL AND GEOCHEMICAL APPROACH

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We integrate XRD mineralogy, elemental analyses, and biomarker evidence to published C-isotope data in order to decipher the paleoredox and paleoclimate conditions within Subunit 2b of the Madotz section (Navarra, Spain), correlative to $\delta^{13}C$ stages C4, C5 and C6 of OAE-1a (Gaona-Narvaez et al., 2013).

Subunit 2b marks a major switch from highly diverse Urgonian-type carbonates to mixed carbonate-terrigenous deposits characterized by low diversity assemblages dominated by orbitolinids, interbedded with bioturbated mudstones, and few pyritic black clay-shales. Subunit 2b is not only characterized by an increase in total clay content relative to the unit below but also by an increase in the kaolinite/smectite ratios. The base of subunit 2b also represents a flooding surface and the onset of a transgressive system (TS) that spans the whole C4 and most of C5 $\delta^{13}C$ stages. Claystones and clay-shales associated with the TS interval are bioturbated and accumulated under fully or intermittently oxygenated water column, hence causing no relative enrichment in organic matter or the redox sensitive trace elements. Nonetheless, reducing conditions and pyrite formation developed in the pore waters.

In contrast, the maximal flooding surface (MFS), within $\delta^{13}C$ stage C5, is associated with pyritic clay-shales showing low bioturbation index, rare fossil content and enriched in organic matter. Pristane/phytane ratio 0.88 and low values of Mn/Al are also consistent with oxygen-depleted bottom waters; and Gammacerane content suggests water-column stratification. The results from the biomarker analyses reveal that the organic matter associated with the MFS is of both marine and continental sources. The MFS shows also the highest content of clays and the peaks of Al, Si, K, Fe, Mg and Ti, of the whole section.

The facies and geochemistry within δ13C stages C4 and C5 are interpreted to coincide with a time of climatic change toward more humid regime consistent with the increased input of terrigenous materials and nutrients that most probably resulted in increased productivity, and development of oxygen depleted bottom waters at the peak of the transgression.

A gradual reduction in the total clay content and kaolinite/smectite ratios is evident in the upper part of subunit 2b which is dominated by Orbitolinid-rich storm beds and shoals. This interval that is partially equivalent to the Highstand System (HS), and spans the terminal part of C5 and the whole C6 $\delta^{13}C$ stages, attests to the slow return to dry conditions at the end of OAE-1a.

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[7] MICROFACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENT OF THE EARLY-MIDDLE JURASSIC IN THE TETHYS HIMALAYA (SOUTH TIBET)

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Jurassic marine strata, sedimentary facies, paleoenvironmental evolution remain poorly constrained. In this paper, the Early-Middle Jurassic strata was defined based on the stratigraphic data from the Wölong section, Tingri County (South Tibet). Subsequently, the high-resolution microfacies study was performed on 292 thin sections of the Wölong section and 207 of the Nianduo section. The Wölong and Nianduo sectons were divided into 17 and 11 microfacies, respectively, and the microfacies types of the two sections are almost same. The feature of microfacies, microacies assemblages, and sedimentary structures reveal that the Early-Middle Jurassic depositional environment evolution of the Tingri and Nyalam areas can be classified into three completely different periods: (1) open-coast tidal flats formed during the early Early Jurassic, dominated by siliciclastic and mixed siliciclastic-carbonate deposits; (2) carbonate platform thrived during the middle Early Jurassic, characterized by high-energy grainstones and plentiful benthos; (3) sea level rising rapidly in the Early Toarcian, the carbonate platform was replaced by middle/outer ramp which is marked by a large quantity of tempestites and low-energy mudstones. Microfacies assemblages and sedimentary sequences show that the paleo-water depth variations overall correspond to the global sea-level changes, sea level rising in the Early Sinemurian and Toarcian of which play a key role in altering the depositional system of South Tibet.

The comparison between the Tethys Himalaya (South Tibet) and the tropical/subtropical zones of the Western Tethys and Panthalassa was carried out based on the processes of paleoenvironmental evolution. It is most probably that the mixed deposits gradually transform into carbonates owing to sea-level rise, improved ecological conditions and plate motion which leaded to the South Tibet locating in a latitudinal zone that favors the development of carbonate. Afterwards, carbonate platform was drowned quickly during the Early Toarcian, which is more likely associated with the early Toarcian Oceanic Anoxic Events. With the global climatic and ecological conditions improving once more in the Early Bajocian, the tropical/subtropical shallow-water carbonate platforms were dominated by corals as the reef-building organism. However, the South Tibet was still a carbonate ramp and subjected to the influence of terrigenous clastics, which is possible that South Tibet is located in high-latitude zone due to plate motion, not in favoring of carbonate factories thriving.

Keywords: Jurassic, microfacies analysis, mixed siliciclastic-carbonate deposits, Tethys Himalaya, South Tibet

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[8] CRETACEOUS EUSTASY AND TECTONICS AND PROGRESS ON UPDATED JURASSIC SEA-LEVEL CURVE

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This presentation will address the issue of eustatic and tectonic interactions as exemplified by the Cretaceous stratigraphic record. Recent years have seen a convergence of views between stratigraphy and geophysics and it is now well understood that inherited topographies deeply affect our ability to reconstruct past landscapes and seascapes. Sequestrations of seawater on land or its subduction-related entrainment in the mantle are the only direct methods of lowering global sea level. Sea level can also be modifiedby changing the container capacity of the ocean through numerous interconnected solid-Earth (tectonic) processes. Some of these processes can only refashion landscapes regionally, thus affecting local measures of sea level change.Recent developments in seismic tomography and high-speed computing that allow detailed forward and inverse modeling, combined with new concepts in stratigraphy and geophysics that permit envisioning large-scale transfers of material among depositional centers, have brought us closer to understanding factors that influence landscapes and sea levels and the complex feedbacks. As a result, estimates of the amplitude of long-term eustatic changes have converged using different data sets. We have learned that tectonic processes operating on decadal to multimillion-year time scales are all responsible for retaining lithospheric memory and its surface expression: On time scales of tens to hundreds of years, glacial isostatic adjustments cause local topographic anomalies, whereas postglacial rebound can be enhanced by viscous mantle flow on time scales of thousands to hundreds of thousands of years; on time scales of >1 Myr, oceanic crustal production variations, plate reorganizations, and mantle-lithosphere interactions become more influential in altering the longer-wavelength surface response. Additionally, the lithosphere's rheological heterogeneity, variations in its strength, and changes in intraplate stress fields can also cause regional topographic anomalies, and syn-rift volcanism may be an important determinant of the long-term eustatic change on time scales of 5 to 10 million years. However, despite these remarkable advances, we remain far from resolving the causes for third-order quasi-cyclic sea level changes (~500,000 to 3 million years in duration). For glacio-eustasy to work in the Cretaceous it will require discerning extensive glaciation at higher altitudes on Antarctica and this could be resolved by modeling topographic elevation involving large-scale mantle processes. Extensive sea-floor volcanism, plate reorganizations, and continental breakup events need to be better constrained if causal connections between tectonics and eustasy have to be firmly established. Another promising avenue of inquiry is the leads and lags between entrainment and expulsion of water (i.e., changes in the rates) within the mantle on third-order time scales. Future geodynamic models will also need to consider lateral variations in upper mantle viscosity and lithosphere rheology that require building on current lithospheric strength models and constructing global paleo-rheological models. Deep-drilling efforts will be of crucial importance for achieving the integrative goals.

The presentation will also report of the progress made to date on the revision of the Jurassic eustatic sea-level curve, which is currently underway.

[9] MESOZOIC PLATE TECTONICS AND THE EVOLUTION OF LIFE ON LAND

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At the beginning of the Triassic Pangaea was a huge, high, dry continent. Rivers were relatively steep and straight with narrow floodplains. Continental shelves were narrow. Ecospace variety was minimal. During the Triassic and Jurassic the highlands were worn down, river gradients lessened and floodplains became wider. By Cetaceous time the continents had very low relief and consequently very broad coastal plains. Minor sea level changes would have been recorded as major transgressions and regressions. River courses changed from straight to meandering and a new kind of ecospace, cutoff river meanders forming oxbow lakes, emerged. These formed a perfect habitat for Brian Ford's 'aquatic dinosaurs' (2012, 2014). There were large numbers of lakes, all with about the same depth. The much greater expanses of water on land and adjacent wetlands increased humidity and rainfall on land and educed seasonal temperature variations making a globally more equable climate. This encouraged the growth of coniferous, then broadleaf forests with the deciduous habit evolving in response of high latitude day and night lengths. Continental shelves expanded creating a variety of new ecospaces. With risingsea level shelf water united with those of the open ocean, again changing the ecospace environments. The climax of this plate tectonic drifting state of the planet was reached in the mid-Cetaceous. Then, in the late Cretaceous, with gradually increasing rates of collisions of terranes and continental fragments, high relief again began to appear, and the warm, wet ecospaces become ever more restricted. This scenario, created by plate tectonic evolution drove the evolution of Mesozoic life. It was a history of adaptation to a unique system of evolving ecospace.

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[10] THE CRETACEOUS HOTHOUSE AND THE GREENHOUSE ICE SHEET DEBATE

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An ongoing debate in paleoclimatic research has centered on recognition of brief cooling events during greenhouse climates and their possible links to sea level changes and growth of ice sheets. Evidence for extreme warmth during the Cenomanian and Turonian has been well supported in multiple $\delta^{18}O$ data sets and by discovery of thermophilic animals living at polar latitudes. Additional foraminiferal $\delta^{18}O$ evidence for mid-Cretaceous extreme warmth at high latitudes will be presented. Previous $\delta^{18}O$ and TEX_{86} studies that identified mid-Cretaceous cooling pulses associated with polar ice sheets have been countered by invariant planktic $\delta^{18}O$ signals and absence of co-varying planktic-benthic $\delta^{18}O$ across proposed glacial intervals. Considering the lack of evidence for rapid and globally synchronous changes in sea level during the Cenomanian and Turonian and overwhelming evidence for extreme global warmth during these times, the Hothouse ice sheet hypothesis is no longer considered viable.

[11] EUSTATIC EVENTS AND SEDIMENTATION MODEL TERMINAL MAASTRICHTIAN IN CRIMEA

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Cyclical facial subdivision of the Terminal Maastrichtian allowed to allocate 27 lithogenetic (LGT) and 7 genetic types. Based on the allocation and tracking sequences defined boundaries varying in ranks of the formation of sedimentary tracts. Their succession during the Later Maastrichtian due to changes in tectonic environment and eustatic sea level. The structure of the carbonate complexes realized sedimentation model peripherally a steep ramp that has a slope flexure in its deep-water part.

During Later Maastrichtian of the open shelf relatively deep carbonate and carbonate-clayish facies changes to carbonate facies shallow-shelf plains. This change in facies is typical for of the South-West, Central and Northern Crimea. In South-Eastern Crimea the continental slope faciesto the top section pass into the deep shelf facies.

At the Cretaceous-Paleogene boundary in the entire study area is allocated a characteristic break in sedimentation, lithologicaly expressed in South-Western, Central and Northen Crimea surface of a “hard ground”, and in the South-Eastern Crimea surface of erosion. Danian deposits throughout the shallow subtidal zone facies represented. Thus, Upper Maastrichtian complex of deposits implemented a model of carbonate sedimentation peripheral steep carbonate ramp with a sharp transition to the continental slope in the area of the Central and South-Eastern Crimea.

Comparison relative sea level curve, was built for the Upper Maastrichtian Crimea, with eustatic curve (Hag et al., 2000) and analysis of sediment rocks in different regions of the world can explain many aspects of Later Maastrichtian sedimentation on the study area. Upper Maastrichtian sequences are consistent with the Maastrichtian major regressive eustatic cycle, at the end of the Later Maastrichtian recorded a sharp deepening of the basin, which corresponds to deposits of "Terminal" Maastrichtian determined in coeval deposits in Western Europe.

At the Cretaceous-Paleogene boundary in the study area marked a break in sedimentation corresponding regression phase. Its complition coincides with the drop in global sea level at the end of the Cretaceous - Early Paleogene. Establishment of patterns of cyclical changes lithogenetic and genetic types of rocks, facies change, both laterally and vertically indicates eustatic nature sequences defined by the authors in the Upper Maastrichtian. Change in lateral facies of the Paleogene and long breaks in sedimentation at the Cretaceous-Paleogene testifies not only to eustatic sea, but also the tectonic movements in the study area.

Total in the context of Upper Maastrichtian allocated two sedimentation cyclite corresponding apparently, sequences 4 order and ten parasequence smaller order. The structure of the lower sequence (M21), overlainswith a stratigraphic unconformity at Albian limestones in the sections of the South-Western Crimea, and conformable to Lower Maastrichtian limestones in the South-Eastern and Central Crimea indicates the highest standing relative sea level at the beginning of the sedimentation cycle. At the base of the sequence the deepest sea sediments, presented micrite and silty limestones with detritus bivalves, sea urchins, sponges, foraminifera. Above there are calcareous sandstones, sandy limestones with larger horizons oysters and bivalves formed in the conditions over the area of the shallow subtidal zone. From bottom to top the section content and the dimension of terrigenous material increases.

Thus, the sequence forms a tract of high stand, and its lower boundary coincides with the maximum flooding surface. The abrupt deepening of the basin sedimentation in the following sequence (M22) marked not only a change in the composition of rocks, but a sharp decrease in the number of macrofauna. Sequence Elements are well expressed in all types of sections and correlated area. The composition and facial content of the upper sequence in the "western" and "eastern" sections of the Crimean Mountains are different, which is reflected primarily in the architecture of its constituent elementary cyclites (parasequences). In this last (if they are synchronized or belong to one sedimentation system) exhibit a similar tendency in the change lithotypes. This allows to connect the mechanism of their formation with the changes of the relative sea level.

This sequence has the following structure. The sections of the South-East Crimea it begins with a thin unit ofmudstone with an almost complete absence of micro- and macrofauna and coincident deposites of transgressive system tract. In the most shallow sections of the South-Western and Northern Crimea they correspond to a break in sedimentation, lithologicaly marked surface of a “hard ground”, and within the existing shallow-shelf plains - bioclastic limestone.

The sections of the Central Crimea they correspond to a unit of sandy limestone, in the bottom of the unit is fixed break and interlayer of sandy limestone with a lot of phosphoriteconcretions. The maximum deep-water conditions of accumulation are recorded in the "deep water" sections development mudstones, and "shallow" - packstones and wackstones. Top of the section essentially carbonate deposits are replaced by quartz-glauconite sandstones in South-Eastern Crimea and quartz-glauconite sandstones with many Chlamyses in Southwest Crimea. In the same direction is sharply increased the number and dimension of terrigenous material. The upper limit of the sequence, which coincides with the boundary between the Cretaceous and Paleogene, expressed by the surface of stratigraphic gap.

Analysis of the morphology and structure of the studied sediment facies distribution in area and in time, as well as a comparison with known patterns of carbonate sedimentation bodies suggest that their formation is associated with the middle and outer peripheral portions of the steep carbonate ramp. This model has existed throughout the Terminal Maastrichtian and has undergone significant changes in the Paleogene.

Key words: Maastrichtian, Crimea, Eustatic events, Sedimentation Model

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[12] MARINE REGRESSION AND TERRESTRIAL SEDIMENTATION AT THE TRIASSIC-JURASSIC BOUNDARY: SOUTHWESTERN MARGIN OF THE NEOTETHYS IN THE SALT RANGE, PAKISTAN

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The Triassic-Jurassic boundary represents a mass extinction event but the explanation of both is still strongly debated. The record of sea-level changes in the boundary interval on one hand gives primary information on palaeoclimate and environments and, on the other hand, provides a primary tool for regional or even global correlation. The end Triassic regression is a globally established event. Erosion and karstification at the top of Triassic sediments indicate widespread regression in the European basins. Fluvial channels with erosive bases and reworked Triassic clasts occur in the Lower Jurassic of these basins. Similar features occur at the top of Triassic in Iran where laterite and quartzose conglomerates/sandstones at the base of the Jurassic indicate fluvial/terrestrial onset. Abrupt emergence, erosion and facies dislocation, from the Triassic dolomites (Kingriali Formation) to Lower Jurassic fluvial/continental quartzose conglomerates/pebbly sandstones (Datta Formation) occur in the Tethyan Salt Range of Pakistan. These features indicate marine regression and emergence under tropical conditions, and represent the Triassic-Jurassic boundary in the area. Sedimentological evidences for the globally present Jurassic-Triassic boundary in the Salt Range of Pakistan encourage a detail work in this regard.

Key words: Triassic-Jurassic Boundary, Early Jurassic, Salt Range and Datta Formation.

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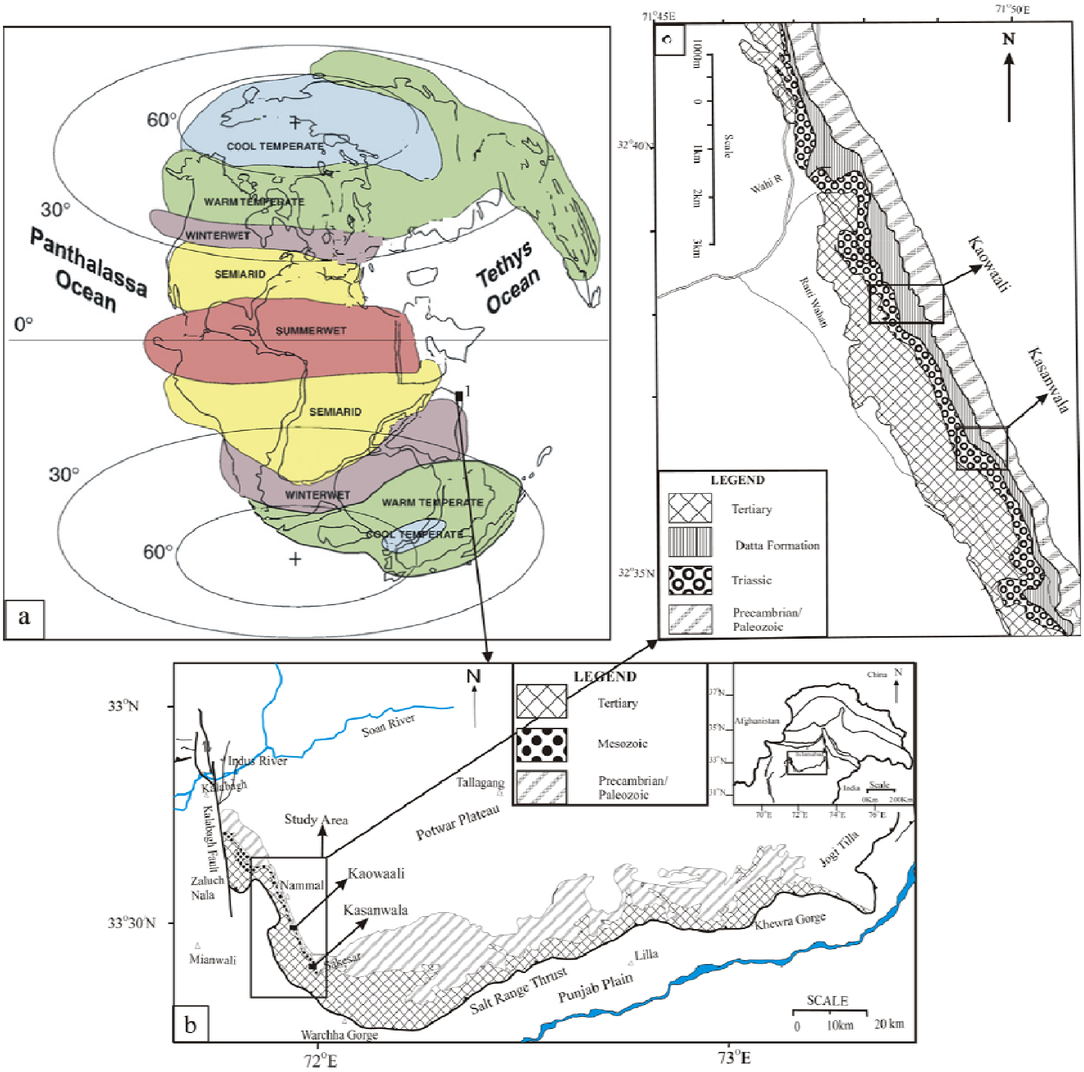

Figure 1. Current and palaeogeographic location of the Salt Range, Pakistan, (a) Early Jurassic palaegeographic location of the study area, showing, 1. Salt Range. (b) Geological map of Salt Range. The map (c) shows locations where the study was conducted (Iqbal et al. 2015).

[13] SEQUENCE STRATIGRAPHY AND SEA LEVEL CHANGE OF THE CENOMANIAN EARLY CRETACEOUS CARBONATE PLATFORM EVOLUTION IN THE MANÍN PELAGIC BASIN (CENTRAL WESTERN CARPATHIANS, SLOVAKIA)

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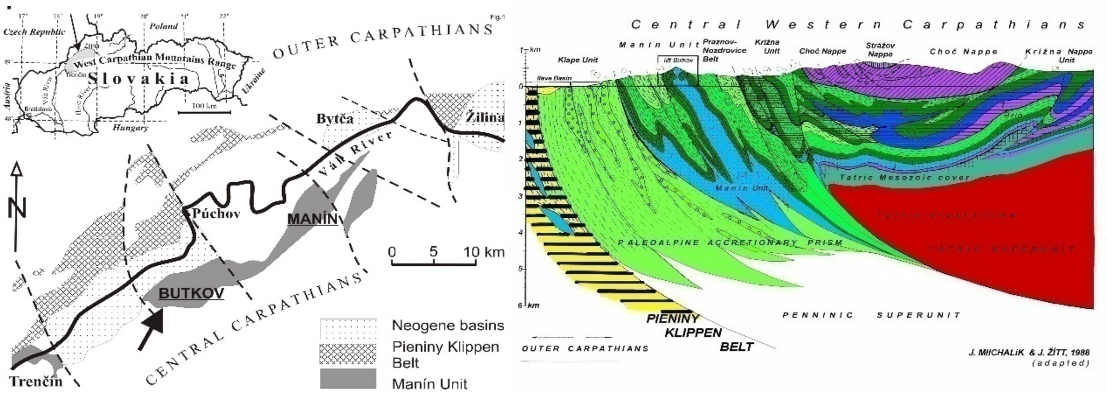
Deposition of Lower Cretaceous hemipelagic planktogenic limestones of the Manin Unit in N part of the Alpine-Carpathian basinal system started after submarine erosion evoked by Late Berriasian extension. Pelagic limestone formations (the Ladce, Mráznica, Kališčo and Lúčkovská formations filled the Manín basin. Epibenthic colonization of soft bottom was gradual and long-lasting. Benthic epifaunal islands formed around hard objects on muddy bottom in the Kališčo and Lúčkovská formations. The uppermost part of pelagic limestone sequence was dated as Late Barremian due to ammonites of the Vanderheckii Zone.

Increasing calcification of benthic organisms (and delivery of debris from prograding carbonate slope) resulted in "Urgonian" carbonate platform growth during Early Aptian. Slope sediments start by fillings of submarine channels being followed by cherty organodetrital limestones of the Podhorie Formation. Rocks are characterized by rather high content of micrite, allochems are represented by fragments of heterotrophic organisms, mostly by echinoderms and molluscs. Orbitolinid foraminifers *Palorbitolina lenticularis*, *Orbitolina (Mesorbitolina) parva*, *Orbitolinopsis simplex* indicate Aptian age. The core of platform is formed of massive organodetrital limestones of the Manín Formation. Orbitolinids and fragment of rudist bivalves are more frequent, algal and coral debris occurs subordinately. These facies represented back reef lagoons and/or deeper parts of outer platform. The presence of planktonic foraminifers of *Ticinella roberti* indicate latest Aptian / Early Albian age of the upper part of the carbonate sequence.

Positive and negative excursions of ^{13}C isotope curve could indicate episodes of environmental changes and their effects on bioproductivity on carbonate platform.

The platform growth stopped during mid-Albian collapse, when hard rock surface bored by infaunal organisms (boring sponges, bivalves) has formed. Hard ground surface is covered by ferrugineous- and stromatolite crusts, or by thin calcisphaerulid glauconite-bearing limestone layer. The sequence was covered by thick Albian-Cenomanian pelagic shales of the Butkov Fm.



Location of the middle Váh River Valley within NW Slovakia (left) and geological cross-section across the border of central Western Carpathians (from NW to SE) showing position of the Manín Unit (right).

[14] SEQUENCE STRATIGRAPHY AND SEA LEVEL CHANGE OF THE CENOMANIAN SUCCESSIONOF CRIMEA--NORTH CAUCASUS AREA AND MANGYSHLAK MTS (W. KAZAKHSTAN)

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The Crimea and North Caucasus. The Cenomanian of the Crimea MTS comprises 70-80 m of rhythmically bedded marly chalk and chalky marls. They show an overall decrease in the clay component towards the top. This sequence contains several regional erosion surfaces. The basal glauconitic marl of the Cenomanian succession rests disconformably on the sandstones of Late Albian (Lowstand System Tract ~ LST). The Lower Cenomanian coincides with Transgressive System Tract (TST) and Highstand System Tract (HST). The top of the Lower Cenomanian is truncated by a next erosion surface (Mid Cenomanian nonsequence). The lower part of the middle Cenomanian ismissing as a result of a short, worldwide regression(Gale et al., 1999). This interval includes TST exactly above erosion surface, and HST. For the upper middle Cenomanian (HST) a cyclic alternation of relatively dark- and light colored marls, interpreted as Milankovich cycles with an alternation of warm and colder epochs (Nikishin et al., 2008). Up section,in the Cenomanian sequence, the amount of benthicmacrofauna decreases, which reflects the general deepening of the basin. The sharp erosion surface represents a sequence boundary correlative with subplenus erosion surface in the Anglo-Paris basin (Gale et al., 1999). Immediately overlying this bed, laminated organic-rich marls at several sections represents the TST and coincides with OAE 2 (Bonarelli) event.

The Cenomanian of the North Caucasus comprises from 40 till 100 m of rhythmically bedded marls, chalky marls and limestones. The same order of sequences set in the Cenomanian of this region. However, more complete than in the Crimea are the LST and TST at the base of the Cenomanian. It is much more common OAE 2, which is dedicated to the terminal Cenomanian and coincides with TST. Based on the stratigraphic completeness all North Caucasian sections are dived into three types (1) sections with complete OAE 2 interval, (2) sections containing OAE 2 sediments overlain by the Middle Turonian and (3) sections marked by the complete erosion of OAE 2 sediments during the early Turonian transgression (Gavrilov et al., 2013). The third type of sections dominated in Crimea.

Mangyshlak Hills. The clastic type of sedimentation is characterized the Mangyshlak region. Sequences in the Cenomanian of Mangyshlak clearly defined by sedimentological criteria. The base of each sequence comprises a thin horizon of phosphatic concretions which rest on an erosion surface and represents an abrupt lithological break (Marcinowski et al., 1996). These sequence boundaries are directly overlain by TST. The lowest part of the Cenomanian coincides with phosphatic conglomerates and represents the TST. The overlain sands and sandy marls are possibly HST. The presence of large carbonate concretions within of the Lower Cenomanian indicates possible onthe existence of another sequence boundary

(Gale et al., 1999). The sequences 1-2 is truncated by an erosional surface overlain by a phosphatic conglomerate which interpreted as lag deposits formed during a transgression. Almost all middle Cenomanian is missing in Mangyshlak (Mid Cenomanian nonsequence). The Upper Cenomanian contains two sequences. The upper part of the second sequence includes organic-rich sediments (black clays and sandy clays), which are interpreted as TST and a local representative of OAE 2.

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[15] UNRAVELING THE PALEOCENE–EOCENE THERMAL MAXIMUM IN SHALLOW MARINE EASTERN TETHYAN ENVIRONMENT: THE STRATIGRAPHIC RECORD IN GAMBA AREA (SOUTH TIBET)

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Despite the increasing understanding of the Paleocene-Eocene thermal maximum in open marine environments, shallow marine settings remain relatively unexplored. We investigated an upper Paleocene to lower Eocene shallow-water sequence in South Tibet in order to generate a stratigraphic framework of the PETM in shallow marine carbonate ramp setting of the Eastern Tethys. The PETM interval is expanded and situated in the boundary of member 3 and member 4 of the Zongpu Formation which is pinpointed on the basis of the carbon isotope excursion together with the sedimentology and biostratigraphy studies. Unfortunately, the sequence is truncated by early Eocene erosion and only the upper part of the PETM interval is preserved. The unconformity at least lasts for 1Ma by the analysis of the larger foraminiferal biostratigraphy.

A prominent negative excursion in $\delta^{13}C$ curves of bulk rock (3.4‰~ 4.9‰) and organic (~3‰) is interpreted as the carbon isotope excursion during the Paleocene-Eocene thermal maximum. In addition to a well-expressed carbon isotope excursion, the position of the Paleocene-Eocene boundary is supported by distinct lithology changes from marly limestone to thick-bedded limestone. Furthermore, benthic foraminifera turnovers coincide with the interval of the PETM and are characterized by the disappearance of SBZ 4 index larger foraminiferal assemblages of *Aberisphaera gambanica*, *Lockhartia conditi*, *Daviesina langhami*, *Lockhartia haimei*, *Lockhartia cushmani, Ranikothalia sindensis* and settlement of completely new SBZ 6 index larger foraminiferal assemblages of *Alveolina pascillata, Alveolina ellipsoidalis, Glomalveolina subtilis, Alveolina aramaea, Alveolina illerdensis, Orbitolites complanatusin*.

The amplitude of the carbon isotope excursion on bulk-rock records is ~3.4‰ in section Zongpu and ~4.9‰ in Zengbudong which is fall between the 2.5‰ ~4‰ of the deep sea bulk carbonates and 5‰ ~6‰ of the terrestrial record and comparable to the values of shallow marine bulk carbonates. The strongly ^{13}C depleted record of our shallow marine carbonates could result from organic matter oxidation suggesting intensified weathering, run off, and organic matter flux.

Key words: PETM, carbon isotope, larger foraminifera, shallow marine, Gamba, South Tibet

[16] GEOCHRONOLOGY OF SINGLE ZIRCON U-PB ISOTOPE IN SOUTH CHINA: INSIGHTS OF THE LATE MESOZOIC TERRESTRIAL BASIN AND STRATIGRAPHY

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A number of Cretaceous continental sedimentary basins were formed by regional extension during the late Mesozoictectonism in E Asia. They were also developed in the Gan-Hang tectonic zone in South China during the same period, mainly outcropping in western Zhejiang, Fujian and eastern Jiangxi. However, the stratigraphic sequence and correlation have been in dispute although the stratigraphic frameworks were already established for decades of years. This is because: 1) terrestrial fossils are not readily indexed in age; 2) highly-frequent terrestrial environment changes led to quick changes of living habit; 3) isotope dating techniques are not in high efficiency and datum quality is not good before 2000s.

Lots of volcanic intercalations/interbeddings provide us opportunities to redefine and calibrate the strata of basins within the Gan-Hang tectonic zone. We have taken over 60 samples at 10 places for zircon U-Pb isotope analysis. Together with former publishedzircon U-Pb isotope dating data (about 18 samples) and other non-zircon isotope data, primary results indicate a different stratigraphic framework from the formers. The key point is that the lithostratigraphic units are not upward sequence and isochroneity. In western Zhejiang, Jiande basin, Yongkang basin, and Jinhua-Quzhou basin have been thought to be successively formed. This work indicates that the Jiande basin and Yongkang basin could be coevally formed, likely starting from the Vanlangian, and then be the Jinhua-Quzhou basin in the late Albian. In the Xinjiang basin of eastern Jiangxi province, the Huobashan Group was not deposited as early as the Jurassic, and could be coeval to the Jiande basin in western Zhejiang. In western Fujian, results indicate the basin group could be initiated in the Middle Jurassic, neither in the Late Jurassic nor in the Early Cretaceous, and the giant nonconformity between the Chishi Group and Jishan Formation had not happened in the interval of the Vanlangian-Hauterivian, but in the Aptian-Albian.

The relationships among the basins suggest that the stratigraphic sequence and correlation would be redefined and adjusted in the terrestrial basins in South China.

[17] DECIPHERING THE EVOLUTION OF OCEANIC ANOXIC EVENT 2 (OAE2)

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Oceanic anoxic event 2 (OAE2), which occurred at the Cenomanian/Turonian Boundary (CTB, ~93.9 Ma), is characterized by enhanced burial of organic matter in ocean basins that was accompanied by a pronounced positive carbon isotope excursion (CIE) in both marine and terrestrial realms, thus representing a major perturbation to global carbon cycle. Although OAE2 is increasingly recognized, its detailed evolution including initiation, maintenance, and termination remains poorly understood. To unravel the evolution of OAE2, we have carried out a high-resolution magnetic and carbon isotope investigation of an expanded Cenomanian-Turonian boundary section at Tingri in southern Tibet, China. The studied section consists of a hemipelagic succession that was accumulated on the northern margin of India plate in eastern Tethys. Close-spacing sampling every 10 to 20 cm was conducted on the 76 m thick section. Magnetic susceptibility (MS) data of the samples display cyclic variations and spectral analysis of the MS data reveals dominant sedimentary cycles with cycle wavelength ratios similar to those of short eccentricity and precession. Thus, sedimentary cycles representing short eccentricity were used to establish an orbital timescale for the section. High-resolution carbon isotope data show a brief negative excursion preceding a prolonged positive CIE. Also, each stage of the positive CIE is not monotonic but contains short-lived, stepwise shifts, suggesting that carbon isotope variations were highly dynamic during OAE2. With the new orbital timescale, the OAE2 interval in the Tibetan section is estimated to last for ~870 kyr, which is in striking similarity to the estimate of 847 to 885 kyr from the CTB stratotype section. Correlation of our new high-resolution data with other OAE2 records permits detailed examination of its evolution, especially for unravelling the complicated feedbacks among sedimentary, biotic, and geochemical processes during this geologically brief event.

[18] METHANE-DERIVED AUTHIGENIC CARBONATES OF MID-CRETACEOUS AGE IN SOUTHERN TIBET: TYPES OF CARBONATE CONCRETIONS, CARBON SOURCES, AND FORMATION PROCESSES

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Methane-derived authigenic carbonates with distinctive structures and morphologies have been documented worldwide, while they are rarely found from ancient strata in the Eastern Tethys Ocean. Methane-derived authigenic carbonates found in southern Tibet aredeveloped in calcareous orsiltyshales of mid-Cretaceous age in the Xigaze forearc basin and in the Tethyan Himalaya tectonic zone. The morphology, mineralogy, elemental geochemistry and the composition of carbon and oxygen isotopes of these carbonates are studied in detail.

The carbonates have nodular, tubular, and tabular morphologies. They are mainly composed of carbonate cement which partly replaces host-sediment grains, siliciclastic sediments comprising mainly quartz and plagioclase feldspar, a few foraminifers, framboidal or subhedral to euhedral pyrite. Carbonate cements dominantly are micritic calcite, and sometimes a few dolomite.

Nodular concretions are characterized by depleted $\delta^{13}C$ values, commonly ranging from -30 to -5‰. From periphery to center, the $\delta^{13}C$ values show a gradual decrease, and the contents of CaO, SiO_2, Fe_2O_3, Al_2O_3, K_2O, TiO_2 mostly show a gradual change. These features indicate that the growth of nodular concretions grew from an early-formed center towards the periphery, and the carbon source of nodular concretions is a mixture of methane, methanogenic CO_2, and seawater dissolved inorganic carbon.

Tubular concretions are characterized by $\delta^{13}C$ values of -8.85 to-3.47‰ in the Shangba Section,and-28.81 to -12.99‰in the upper Gamba Section. Unlike the nodular concretions, tubular concretions show central conduits, which possibly are the pathways of methane-rich fluids, suggesting that the cementation of tubular concretions starts at the periphery and proceeds inward. Besides, tubular concretions show morphological similarity with methane derived carbonate chimneys, pipes and slabs reported in present-day cold-seep settings. We suggest that the carbon source of tubular concretions was a mixture of seawater dissolved inorganic carbon and oxidized methane formed by hydrate release. Tabular carbonates are characterized by$\delta^{13}C$ values of-21.87 to -6.67‰. These depleted values suggest that the carbon of the tabular concretions derives from at least in part from AOM.

Key words: Carbonate concretions, methane, carbonisotopes, mid-Cretaceous, southern Tibet

[19] TERRESTRIAL PALEOCLIMATIC EXPRESSIONS OF APTIAN-ALBIAN CARBON ISOTOPE EXCURSIONS

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Aptian-Albian marine carbon isotope excursions (CIEs) are traced into terrestrial strata with high chronostratigraphic fidelity because of the tight temporal coupling of $^{13}C/^{12}C$ ratios between global marine, atmospheric, and terrestrial carbon pools (Ludvigson et al., 2015). This phenomenon results from the annual time scales of global atmospheric mixing, the instantaneous $\delta^{13}C$ equilibration of atmospheric CO_2 with marine DIC at the sea surface, and the simultaneous capture of atmospheric $\delta^{13}C$ values through carbon fixation by terrestrial photosynthesis—subsequently buried in the rock record as terrestrial organic matter. Correlated terrestrial records of Aptian-Albian CIEs from stacked paleosols in the Cedar Mountain Formation (CMF) of Utah in North America (Ludvigson et al., 2010), and lacustrine marls of the Xiagou Formation (XF) in Gansu Province, China(Suarez et al., 2013) offer unique insights into the terrestrial paleoclimatic impacts of the CIEs that were recorded by terrestrial carbonate geochemistry. The late Aptian C10 positive CIE in the CMF was expressed as a positive $\delta^{18}O$ excursion recording an aridification event, and carbonate clumped isotope paleothermometry indicates that the early Aptian C7 positive CIE in the XF was expressed as a warming event.

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[20] MESOZOIC GREENHOUSE WORLD OF PAKISTAN AND SEA LEVEL CHANGES

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Greenhouse (warm) climates and icehouse (cold) climates show alternation in the Pre-Mesozoic rocks of Pakistan, however the dominant climate in the Paleozoic was the Greenhouse climate or warm climate. Only a few tillite/till evidences are found in the Cambrian of Potwar (Upper Indus) Basin which shows Icehouse climate or cold climate. However in the Mesozoic and Cenozoic both are represented by Greenhouse (warm) climate in Pakistan and there are no evidences of Icehouse climate. The Mesozoic Strata of Pakistan have diverse paleoenvironments like deep marine to neritic/shallow marine, tidal, deltaic, sabkha type supratidal evaporitic, terrestrial/continental, lacustrine, colluvial and eolian. The Tethys sea level curves of Sulaiman (Middle Indus) and Kohat-Potwar basins show considerable drop due to first collision of Indo-Pak with Afghan block of Asia. It further regressed and permanently closed from most part of Pakistan during Early Oligocene. Due to recent geological and paleontological exploration, Pakistan appeared first time in the world dinosaur map. The Mesozoic Terrestrial Ecosystem represents body fossils of titanosauriforms, titanosaurian sauropod and abelisaurian and noasaurian theropod dinosaurs, pterosaurs and mesoeucrocodiles; and footprints and trackways of titanosauriforms, titanosaurian sauropods and theropod dinosaurs, and a wood fossil of large gymnosperm. The Mesozoic Marine Ecosystem of Pakistan represents many invertebrates and some fish body cross section.

Keywords: Paleozoic, alternated Greenhouse and Icehouse climate, Mesozoic, Greenhouse World, Warm climate, Sea Level Changes, Pakistan.

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[21] GOSAU-TYPE BASINS OF THE SOUTHERN CARPATHIANS: TECTONIC, CLIMATE AND SEA-LEVEL FLUCTUATION CONTROL

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During the Early Cretaceous, within the Berriasian-Early Aptian interval, the Southern Carpathian region was covered by a carbonate platform, i.e. the Getic Carbonate Platform. A drawing of this platform took place in the Early Aptian, as in the most Tethyan areas. The reef limestones of the Urgonian facies were replaced by continental deposits, such as red beds with bauxite in the western part of the Southern Carpathians, including the Haţeg Basin. In the eastern part of the Southern Carpathian belt, the post-Aptian sedimentation developed in small basins, with a west-east extension, in which the Urgonian limestones are covered by shallow water sediments.

In the Haţeg basin, a fluvial-lacustrine deposition, with sandstones and coal-bearing marls, characterized the Late Aptian-Albian interval, followed by a shallow marine sedimentation, including rudist limestones upwards the Cenomanian. According to the Austroalpine definition, these deposits may be grouped into the Lower Gosau Subgroup (shallow marine facies) and are followed, in the western part of the Southern Carpathians, by Coniacian-Campanian turbidites, i.e. the Upper Gosau Subgroup (deep marine facies). A re-occurrence of the shallow marine deposits appears in very limited areas of the Southern Carpathians western basins, within the Late Campanian-Early Maastrichtian interval.

In the eastern and central parts of the Southern Carpathians, in the Olăneşti, Cheia and Brezoi basins, the Upper Cretaceous shallow marine sedimentation is periodically interrupted by a turbidite deposition. The end of the Cretaceous, i.e. the Campanian-Maastrichtian interval, is characterized by the deep-marine sedimentation.

Most probably, the factor controlling the changes in the paleosetting upwards the Albian is the Upper Cretaceous active tectonic in the Southern Carpathians, including the mid Cretaceous and the Laramian movements. On the other hand, sea-level fluctuations and climate modifications enhanced the effects of the tectonics.

[22] SEQUENCE STRATIGRAPHY OF THE MIXED SILICICLASTIC-CARBONATE SYSTEM OF THE CENOMANIAN RAHA FORMATION, BAKR OIL FIELD, GULF OF SUEZ, EGYPT

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The first sequence stratigraphic study by the palynological analysis and lithological character of the Raha Formation has been carried out in Bakr oilfield which is the most productive oilfield in the Gulf of Suez. Sixty rock cutting samples of the Raha Formation from the three wells have been investigated. These samples are belonging to Cenomanain age. The Raha Formation corresponds to a second-order depositional sequence which divided into six complete third-order depositional sequences and two incomplete ones. Those sequences were constructed based on the comprehensive interpretation of the depositional paleoenvironment by using the palynofacies analysis as well as the lateral and vertical changes of facies between the three studied wells. These sequences of the Raha Formation were deposited within a continental shelf setting from supratidal to outer neritic conditions, reflecting low-rate positive accommodation (<200m during ~6 My). Moreover, the palynofacies analysis of the Raha Formation demonstrates a long-lived transgressive phase interrupted by short-lived regressive phase. A basin fill model of Bakr oilfield was constructed to clarify the lateral and vertical extension of the third-order systems tracts and bounding surfaces within the oilfield as well as the basin evolution.

[23] FLORAL AND CLIMATE CHANGE AT THE CRETACEOUS-PALEOGENE BOUNDARY IN NEW ZEALAND

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New Zealand is one of the few places where a terrestrial Cretaceous-Paleogene boundary is exposed. There is a distinct change in macrofloral composition from Late Cretaceous to the Paleocene, although the details at the actual boundary remain sparse. The most striking change is in the Araucariaceae, which were virtually ubiquitous in the Late Cretaceous, but rare in the Paleocene. This 'rule of thumb' for recognising the boundary is clearly not global – as Araucariaceae macrofossils became rare earlier in some parts of the world, and remained in others. This suggests climate change as the cause. This paper summarises araucarian distribution in the Cretaceous-and Paleocene in the context of current understanding of the climate.

Key words: Floral change, climate, Cretaceous-Paleogene boundary, New Zealand

[24] MID-CRETACEOUS EVENTS IN THE EASTERN CARPATHIANS: TECTONIC AND EUSTATIC CONTROL

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The Eastern Carpathians evolved in an extensional regime since the Early Jurassic, followed by a compressional from Mid-Cretaceous onward (Săndulescu, 1984). The sedimentation in the Moldavide basin, which represents the outer (eastern) depositional area of the Eastern Carpathians, started with lowermost Cretaceous, i.e. Valanginian-Albian, black shale (BS), followed in most of the tectonic nappes by Cretaceous Oceanic Red Beds (CORB)(Hu et al., 2012), within the Albian-Cenomanian boundary interval.

The transition from BS to CORB is not synchronous in the different areas of the Modavide Nappe system, showing different age from W (Inner Moldavides) towards E (Outer Moldavides). In the outer part of the basin, the CORB facies started in the Lower Turonian, while in the inner parts, the red shale facies began to be deposited from the Albian-Cenomanian boundary interval.

The black shales were accumulated on the passive margin and in an abyssal area of a narrow and deep basin, being characterized by anoxic, suboxic and dysoxicfacies. Beside black shales and thin turbidites, the sandy high density turbidites was recognized in the Albian deposits. These consist of carbonate sandstones and calcirudites in the more proximal part of the basin and quartz arenites and graywackes in the distal areas. The CORB facies is also accumulated in a deep and oxic palaeoenvironment, as indicated by the benthic microfaunal assemblages.

We hypothesize that the asynchronous BS-CORB transition as the different lithology of the Albian from the other Lower Cretaceous indicate the presence of high intrabasinal areas, i.e. cordilliera, generated by the inversion of at the beginning of the Aptian-Albian compressional regime of the Eastern Carpathians. The cordillieras acted as intrabasinal source areas supplying siliciclastic and granitoides in the distal regions of the basin; hence, these cordillieras led to the separations of small sub-basins, characterized by different kind of sedimentation.

Besides regional events, such as the influence of the tectonics on the palaeosetting, some global events, such as the occurrence of OAE1d within the Late Albian, have been observed. Noticeable, this anoxic event was pointed out both in the inner (western) and outer (eastern) parts of the Moldavide nappes.

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[25] STABLE ISOTOPE PALEOHYDROLOGY OF PEDOGENIC CARBONATES FROM THE WEDGE-TOP DEPOZONE OF THE NORTH AMERICAN SEVIER OROGENIC BELT

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Stable isotopic paleohydrologic data from mid-Cretaceous paleosols in North America are summarized by (Suarez et al., 2011).From 40-50°N paleolatitude, sideritic paleosols predominate, indicating paleoenvironments with positive P-E balances. Exceptions occur on leeward side of the Sevier Orogen, where calcic paleosols record paleoenvironments with negative P-E balances inthe orographic rain shadow. Stratigraphic sections in the Wayan Fm of Idaho (WF) and Blackleaf Fm (BF) of Montana were sampled from this depozone. Both units consist of stacked m-scale mudstone paleosols separated by m-scale sandstone-siltstone beds. Both units were sampled for organic carbon isotope profiles. B-horizons from 12 well-developed paleosols were sampled for volcanogenic zircons, and are being analyzed for U/Pb dates, the first of which from the WF has produced an age of 101.24±0.96 Ma. This same WF section has a trend of $\delta^{13}C$ values decreasing upward from -24 to -27‰ VPDB, suggesting correlation to the late Albian interval above the C15 carbon isotope feature of Bralower et al. (1999). Pedogenic carbonates from the WF and BF principally consist of micritic calcites that yield meteoric calcite lines (MCLs) with $\delta^{18}O$ values that range between -10.59 up to -8.39‰ VPDB. These MCL values at 42-43°N paleolatitude produce estimated paleoprecipitation$\delta^{18}O$values of -9.24 to -7.04‰ VSMOW, a range that is consistent with the estimates of Suarez et al. (2009) at the same paleolatitudes. These results indicate that despite the orographic rain shadow effect, the processes of meridional atmospheric moisture transport over mid-Cretaceous North America were similar to those in more humid mid-latitude paleoenvironments elsewhere in the continent where paleoprecipitation$\delta^{18}O$values were estimated using pedogenic siderites.

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[26] INTEGRATING PALEOENVIRONMENTAL AND CLIMATE CYCLICITIES – NEW APPROACHES AND CONCEPTS FOR THE NON-MARINE LOWER CRETACEOUS

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Geological correlations in the non-marine realm ('continental' aquatic, limnic and terrestrial paleoenvironments) are still fraught with considerable problems and limitations on a regional scale, but especially on supraregional (i.e., inter-basinal) to global scales. Thereby, any serious attempts at dating and chronological linking of events documented by the respective deposits are often hampered, let alone correlation to the marine standard successions. While recent refinements of the geological time scale have made major advances for the marine Cretaceous to yield a resolution on Milankovitch scales (405 and 100 kyr eccentricity cycles), dating of Cretaceous non-marine successions remains notoriously insufficient and is often less accurate than stage level. This also applies to the rather well-investigated "Purbeck-Wealden interval" (uppermost Tithonian to Barremian/lowermost Aptian), the approximate interval named after the English "Purbeck" and "Wealden" largely non-marine depositional facies (now Purbeck Group and Wealden Supergroup respectively) during which broadly similar facies existed in many parts of the world. As a consequence the tremendous non-marine Lower Cretaceous archives are still practically excluded from being considered relevant for the stratigraphic record and for the work on the high-resolution Cretaceous timescale. In addition, studies on non-marine Cretaceous stratigraphy, climate cycles and environmental changes (including control factors and feedback mechanisms) are few, primarily as a result of the lack of high-resolution stratigraphy and correlations to the marine record.

During the last two decades, progress in Cretaceous climate change and marine cyclostratigraphy as well as progress in non-marine chemostratigraphy, geochronology, magnetostratigraphy and biostratigraphy (including the revival of non-marine ostracod biostratigraphy) has led to changing concepts and approaches towards an improved non-marine Cretaceous chronostratigraphy, and towards adequate proxies and methods for improving marine to non-marine correlations (e.g. Ludvigson et al., 2015; Robinson and Hesselbo, 2004; Sames and Horne, 2012). Such correlations should ideally be based on signals and proxies that are recorded in – or affecting both – settings in a similar way. Besides the characteristic remanent magnetization signal, correlations should be based on *the* single synchronous and continuous signal recorded in various proxies in both marine and non-marine successions: astronomically forced, short- (< 1 myr) and medium-term (a few myr), cyclic global climate change. With respect to the English Purbeck and Wealden, there have been suggestions concerning the linkage of ostracod 'faunicycles' (after F.W. Anderson, see Horne, 1995 for discussion) to Milankovitch (and corresponding climate) cyclicities, but conclusive and convincing analyses are lacking to date.

Within the scope of a new interdisciplinary project and multi-proxy study "Lower Cretaceous Climate and Non-marine Stratigraphy (LCCNS, running 2015–2018)", funded by the Austrian Science Fund (FWF, project P 27687-N29), the European non-marine Lower Cretaceous record – the English Wealden to be exact – will be used as a test site for integrating ostracod biostratigraphy and assemblage changes, and cyclostratigraphy (orbitally driven climate cycles). Ostracods (microcrustaceans with a calcified bivalved shell) are one of the most useful biostratigraphical and paleoenvironmental tools in Lower Cretaceous non-marine sequences. During the past two decades, research progress in late Mesozoic non-marine ostracods has led to their extended applicability, whereas their wide dispersal ability has become a key consideration in their supraregional (inter-basinal to global) biostratigraphical utility (Sames and Horne, 2012). Based on new samples from a selected interval of the Lower Weald Clay Formation, the new integrative methodology applied in this project aims at correlating ostracod faunal composition changes with variations of geochemical and sedimentological parameters through time, as well as inferring the controlling (paleoenvironmental) factors and their regulating mechanisms ("climate changes", orbital cycles?). The central approach is combining 1) non-marine ostracod ecostratigraphy, 2) lithologic parameters and sediment geochemistry, and 3) stable isotope geochemistry of ostracod shell plus 4) magnetostratigraphy for chronological control, and to then 5) integrate the results of the previous methods and perform statistical tests for cyclicities.

The consideration that paleoenvironmental changes – that control assemblage changes of microfossils along with changes of lithological and geochemical parameters of corresponding sedimentary successions – are climatically and thus, ultimately, astronomically controlled, leads to the coherent approach that these cyclic(?) changes can be analysed and tested for cyclostratigraphic use.

Consequently, the central approach of the project is to "turn the tables" in that the strong facies control and change (widely considered as a substantial drawback of stratigraphy in non-marine deposits and of the supraregional biostratigraphical utility of non-marine ostracods) shall be re-analysed and tested for cyclostratigraphic use based on various parameters. The combination of different methods and data allows the evaluation of their utility on different chronological and geographical scales. These methods can then be efficiently applied on larger scopes and to larger datasets. The project represents a pioneering study in this area of research and is going to contribute to 1) the chemo- and magnetostratigraphy of the English Wealden, and the nature of its cycles, 2) the development of a Lower Cretaceous non-marine cyclostratigraphy, and 3) the understanding of Early Cretaceous climate change. Based on the hypothesis of a well characterized non-marine cyclostratigraphy, main objectives on a longer term are 1) to better link marine and non-marine Cretaceous successions, 2) to enhance the resolution in the considerable Lower Cretaceous non-marine global record, and 3) to integrate these data into the Cretaceous timescale.

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[27] CONTINENTAL CRISES OF THE JURASSIC: A BRIEF INTRODUCTION OF IGCP 632

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The Jurassic Period witnessed the three major bioextinct events, the Triassic-Jurassic mass extinction event, the Toarcian extinction event and Tithonian extinction event. All these events are closely related with the events of fragmentation of Pangea, huge flood basalt, elevation of CO_2 and geographic changes. These extinction events, particularly the marine Triassic-Jurassic and Toarcian extinct events, have been studied by numerous authors, though there are many contents of them which are remained to be constrained. The terrestrial Jurassic crises were very serious and affected huge continental areas. However, the mass extinction patterns, causes and their effects in lake ecosystems, particularly in their correlation between Southern and Northern hemispheres, have not yet been studied in detail, and the response relations between terrestrial and marine crisis events have not been clarified. To clarify these scientific problems is one of the major aims of IGCP 632 (Continental Crises of the Jurassic: Major Extinction Events and Environmental Changes within) built on the successful IGCP 506 (Marine and Non-marine Jurassic: Global Correlation and Major Events) (2005–2010).

[28] BIOMARKER CHARACTERIZATION OF THE NEGATIVE CARBON ISOTOPE SHIFT IN SEGMENT C2 OF THE EL PUI SECTION, ORGANYÀ BASIN, CATALUNYA, SPAIN

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Variations in the carbon isotope record of Lower Cretaceous deposits are widely recognized to show intermittent prominent negative and positive spikes, and the consistent pattern of coeval chemostratigraphic curves thus documents shifts that signal overall simultaneous responses of temporal changes in the ocean carbon reservoir. The original standard pattern registered by the $\delta^{13}C_{org}$ and $\delta^{13}C_{carb}$ stratigraphy in Lower Aptian sediments of the Alpine Tethys was subdivided in distinct isotope segments coined (C1 to C 8, Menegatti et al., 1998), which have been extensively replicated elsewhere. The calibrated chemostratigraphic curve thus offers further means for correlation and to assess approximate geochronology(Sanchez-Hernandez et al., 2014;Sanchez-Hernandez and Maurrasse, 2015).

Carbon isotope segment C2 is the longest interval preceding the segments assigned to anoxic event 1a (OAE 1a) (C3 – C6), and in expanded sections of the Tethyan realmincludes a marked negative inflection of ~0.5 to 1.5 ‰ that characterizes the overall pattern of the isotope values within that interval (e.g. Tunisia, Heldt et al., 2008; Cismon APTICORE, Italy; and Santa Rosa Canyon, Mexico, Li et al., 2008). Various proxies (TIC; TOC; $\delta^{13}C_{org}$, petrographic, microfacies, paleontological and biomarker (*n*-alkanes) characterization) wereinvestigated to provide further insight into the character of the depositional environment associated with this negative inflection. The results reveal relative monotonous contents with no difference in biota between the time before, during or after the negative inflection that includes mainly low diversity, but abundant calcareous nannofossils responsible for most of the TIC, average ~ 72.3 CaCO3 %, very rare small-sized planktonic foraminifera, and an abundant roveacrinid fragments. The lipid fraction of biomarkers shows that the organic matter is mainly derived from algal and microbial sources with the highest values being dominated by the short-chain length homologues ($\leq nC_{19}$). In addition we see some contribution from aquatic vegetation (nC_{20} through nC_{25}) and little contribution from higher plants ($>nC_{25}$). The latter is further confirmed by the terrestrial input value, or so-called TAR $((nC_{27}+nC_{29}+nC_{31})/(nC_{15}+nC_{17}+nC_{19}))$, which averages 0.36. Further investigations of algal contributions (perhaps CO_2-using Rhodophyta) may provide an improved understanding of their role on the local variations.

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[29] PALEO-DEPOSITIONAL ENVIRONMENTS OF THE CENOMANIAN ROCKS IN THE SINAI PENINSULA, NE EGYPT: AN IMPLICATION FOR RAMP SETTING AND SEA-LEVEL CHANGE

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In Sinai Peninsula, the exposed Cenomanian rocks have different synonymies of rock units namely Raha Formation, Galala Formation and Halal Formation at south, central and north Sinai, respectively. Five lithostratigraphic sections of the exposed Cenomanian succession in the Sinai Peninsula, NE Egypt, are described and interpreted on the basis of field observations and facies analysis in order to reconstruct their paleo-depositional environments. Based on their lithologic characteristics, the Cenomanian successions consist of mixed siliciclastic–carbonate rocks. The carbonate rocks are dominated in the northern and eastern parts of the study area, whereas the siliciclastic rocks increases southward. Detailed petrographic investigations made it possible to recognize several clastic and carbonate facies types. The facies recognized and their related palaeoenvironments document a lateral transition between inner- and mid ramp settings. The inner-ramp setting occurs in the south and west central Sinai where the peritidal flat, lagoonal, high-energy shoals facies dominate. The mid-ramp setting is assumed to have developed in the north and east central Sinai where intertidal and low-energy subtidal facies interfingers with a few storm-influenced deposits occur. The main factors controlling ramp deposition were eustatic sea-level fluctuations combined with environmental influences such as autochthonous carbonate productivity and siliciclastic supply. The studied Cenomanian deposits were finally drowned towards the close of Cenomanian time, where open deep marine facies of the Upper Cenomanian-Lower Turonian Abu Qada Formation were developed. Conclusively, the area investigated in Sinai was part of a broad shallow carbonate platform that was influenced by terrigenous input from the continent (at the southwestern margin of the study area) and sea-level fluctuations of the southern Tethys (at the northeastern margin of the study area).

Key words: Cenomanian Raha/Galala/Halal Formation, Mixed siliciclastic/carbonate, Ramp facies, Eustatic sea-level change, Sinai, Egypt.

[30] INTERNATIONAL GEOSCIENCE PROGRAM PROJECT IGCP 609: GREENHOUSE CLIMATE SEA-LEVEL CHANGES

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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-level change, a better understanding of the record of past sea-level changes and controlling factors especially during greenhouse climate phases is essential. UNESCO IGCP 609 addresses correlation, causes, and consequences of significant short-term sea-level changes during the last major greenhouse episode of Earth history, the Cretaceous. 3rd to 4th order (kyr to a few Myr), sea-level changes are recorded in Cretaceous sedimentary sequences. The mechanisms for these are controversial and include brief glacial episodes, storage and release of groundwater, regional tectonism and mantle-induced processes.

Based on the progress in the GTS, it is now for the first time possible to correlate and date short-term Cretaceous sea-level records with a resolution appropriate for their detailed analysis. Orbital cycles of various length are increasingly identified in the Cretaceous marine stratal record, and are being used to assess the duration of events and intervals, and to date stage boundaries and bio-zones at high precision. Proxies for sea-level changes in deeper-water shelf to pelagic archives are integrated within a high-resolution and high-precision time scale, such as high-resolution carbon isotopes (climate-driven carbon isotope cyclicity), mineralogy (i.e. distribution of phyllosilicates), grain-size analysis (silt/clay ratio in pelites), sediment geochemistry (e.g. uranium peaks during sea-level rise; Sr/Ca ratios where Sr-rich shelf carbonates weather at times of sea level lows and introduce more Sr into the ocean), and strontium isotopes (continental erosion vs. magmatic values). Further proxies that are related to climate and especially weathering, and thus may relate to sea-level fluctuations, are non-traditional isotope systems like Os, Li, but include also mineralogical changes in clay mineral assemblages (e.g., kaolinite+smectite versus illite+chlorite) or minerals that are weathering sensitive (e.g., feldspar and certain heavy minerals, Wendler et al., 2011). Thus, IGCP 609 investigates in detail climate-related eustatic sea-level cycles, in order to differentiate and quantify both short- and long-term records.

Prominent sea-level fluctuations during major greenhouse episodes of the Earth are often explained by the presence of ephemeral ice sheets even during extreme ‘hothouse’ phases such as the mid-Cretaceous. However, the possible effect of groundwater storage and release on sea-level change has been widely underestimated in its order of magnitude. It is considered to constitute a water volume that is about equivalent to today’s ice volume, thus corresponding to a potential sea-level change of up to ca. 50 m, applying isostatic adjustment. Groundwater aquifer storage, including both freshwater and saline pore waters above sea level, exceeds lake and river storage capacities by several orders of magnitude.

The term “limno-eustasy” was introduced by Wagreich et al. (2014) to describe both the effects of water volumes resulting from groundwater and lake storage or discharge on sea-level fluctuations during ‘hothouse’ climate. Evidence for limno-eustatic cycles during supposed ice-free periods of the mid-Cretaceous come from wet-dry weathering cycles and high-resolution stratigraphic correlations between marine and continental lake archives, i.e., lake-level and sea-level fluctuations that are recorded in an out-of-phase relation in such a way that a major marine sea-level lowstand corresponds to a lake-level highstand (i.e., water ‘removed’ from the sea and stored on the continents), and vice versa. Tests using the Turonian to Campanian Late Cretaceous record of the long-lived lacustrine Songliao basin in China indicate such an out-of-phase relation, and thus support the limno-eustatic hypothesis (Wagreich et al., 2014).

Compelling evidence that aquifer charge/discharge could drive eustasy comes from the observation that pervasive astronomically-driven Cenomanian-Turonian sea-level cycles are linked to cycles in continental weathering and hence to systematic changes in precipitation. Presence of weathering sensitive minerals in transgressive phases suggests dry climate, while regressive to lowstand phases show minor amounts of weathering sensitive minerals consistent with humid climate (Wendler et al. 2014, Wendler et al. in press).

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[31] STRATIGRAPHY AND SEA-LEVEL CHANGE AROUND THE SANTONIAN-CAMPANIAN BOUNDARY INTERVAL

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The Gosau Group successions in the Northern Calcareous Alps of Austria and Germany provide sections that allow the integration of various stratigraphic signals from macro- and microfossils to chemostratigraphy and magnetostratography. Sections in the area of the Gosau valley, e.g. the Postalm section (Upper Austria - Salzburg) expose a Santonian to Maastrichtian succession of neritic to bathyal sediments. At the Postalm, the Santonian-Campanian boundary interval comprises a deepening succession from a sandy conglomerate with a hardground on top, overlain by grey to yellowish shelf marls grading into red marly limestones. The base of the Campanian can be defined by magnetostratigraphy, i.e. the reversal from Chron C34n (the Long Cretaceous Normal Polarity-Chron) to C33r. A 1 m thick interval of unusual high magnetic susceptibility values is present at the end of chron C34n (latest Santonian).

Two of the main suggested plankton biomarkers to pinpoint the Santonian-Campanian boundary, i.e. the first occurrence of the nannofossil *Broinsonia parca parca* and the last occurrence of the planktonic foraminifer *Dicarinella asymetrica* occur in close proximity to the reversal. Strontium isotope stratigraphy indicates a value of 0.707532 for the base of the Campanian in the Postalm section. Carbon isotopes show a positive excursion near the boundary, i.e. the Santonian-Campanian carbon isotope event.

Oxygen isotopes show a negative excursion slightly below the Santonian-Campanian boundary, followed by a trend to more positive values. Together with the magnetic susceptibility data, sequence stratigraphy interpretations and global correlations a sea-level lowstand can be inferred to occur just at the boundary, preceded by a rather short-duration sequence of late Santonian age, and a longer sequence of early Campanian age. The inferred lowstand at the Santonian-Campanian boundary, at the base of chron C33r, is also characterized by a significant rudist extinction event.

[32] FOSSIL WOOD DIVERSITY AND TERRESTRIAL PALAEOCLIMATE VARIATION: NEW DATA FROM THE MESOZOIC OF CHINA

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Fossil wood is one of the significant proxies for palaeoclimate and palaeogeographical reconstruction of the terrestrial ecosystem in earth history. Diverse wood fossils have been reported in China over the past few decades, ranging in age from the Late Palaeozoic to the Cenozoic. In recent years, some new data on fossil wood have been documented from a variety of localities in China, including the Late Triassic and Late Jurassic in the Sichuan Basin, the Jurassic and Cretaceous in the western Liaoning Region. A new conifer wood *Xenoxylon guangyuanense* sp. nov. was recognized in the Upper Triassic Xujiahe Formation in the Sicuan Basin, thus indicating a short-term climate cooling event in the Late Triassic interval, sandwiched within a period during which warm and wet climate condition largely prevailed over lower latitude regions of the Northern Hemisphere. In Jianchang region of western Liaoning, twowell-preserved fossil wood taxa, *Protaxodioxylo njianchangense* Tian et Wang sp. nov. and *Xenoxylon peidense* Zheng et Zhang was recognized from the Tiaojishan Formation. These records add new data for understanding the fossil wood diversity, floral composition and paleoclimate of the Middle to Late Jurassic deposit. The occurrence of *Xenoxylon* and *Protaxodioxylon* implies a cool, wet and seasonal climate condition during the Middle to Late Jurassic transition in western Liaoning region, and provide new insights into the close relationship of the associated earliest known feathered dinosaurs. In addition, several structurally preserved conifer wood specimens from the Lower Cretaceous Yixian Formation are investigated, based on collections from the Heichengzi Basin in Beipiao of western Liaoning. Four species referred to four genera of fossil wood are described, including *Taxodioxylon heichengziense* sp. nov., *Thujoxylon beipiaoense* sp. nov., *Sciadopityoxylon liaoningense* Ding and *Protocedroxylon shengjinbeigouense* sp. nov. Systematic analysis of the floral constitution indicates that the petrified forests of the Yixian Formation are dominated by conifers, represented by Podocarpaceae, Sciadopityaceae, Pinaceae, Cupressaceae and Taxodiaceae in the western Liaoning region. Palaeoclimatical analysis of the fossil wood assemblage implies that the Yixian Formation was dominated by a cool, wet and seasonal climate in the western Liaoning region. This provides additional hints for finally shedding light on the palaeoclimate variations and potential links to the occurrences of feathered dinosaurs of the Jehol Biota.

Key words: fossil wood, diversity, palaeoclimate, Mesozoic, China

[33] RECONSTRUCTING PELAGIC PALAEOENVIRONMENTS FROM THE R. CALCARATA ZONE- A CASE STUDY FROM THE AUSTRIAN ALPS

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The late Campanian *Radotruncana calcarata* Taxon Range Zone was subject to intense investigation in two sections of the Austrian Alps. The Postalm and the Oberhehenfeld section display pelagic palaeoenvironments from the two opposite margins of the Penninic Ocean. Postalm section displays cyclic limestone-marl alterations (representing precession signals) and is located in the Northern Calcareous Alps, Oberhehenfeld predominantly displays greyish marls and is assigned to the the informal unit "Buntmergelserie" of the Ultrahelvetics.

The *R. calcarata* interval can be used as a reliable biostratigraphic marker horizon. Due to its rather short duration and existing cyclostratigraphic models (e.g. Wagreich et al., 2012) the *R. calcarata* Total Range Zone qualifies as well defined framework to trace short term changes in microfossil assemblages. Therefore, it is possible to follow developments in foraminiferal communities and to record local biostratigraphic events (in both planktic and benthic foraminifera).

The reasons for the sudden appearance and disappearance of the fossil marker species itself are subject to speculation. The evolution of *R. calcarata* appears to be closely linked to changes in the ocean's properties that could be related to the late Campanian/Maastrichtian cooling event.

Few high resolution studies on the quantitative composition of foraminiferal assemblages from pelagic sections exist. Data from the Postalm section were assessed per limestone-marl couplet (presumably representing precession cycles), providing a quantitative record of foraminifera communities from the Penninic Ocean in "per cycle" resolution. The opportunistic genera *Heterohelix* and *Hedbergella* are dominant and represent more than 60 percent of the foraminiferal assemblage. Globigerinelloids and archaeoglobigerinids are prominent faunal elements at Postalm section and are represented by up to 20 percent. Globotruncanids are specialist taxa and comparatively rare at Postalm section. Benthic foraminifera are present in every sample but vary in numbers. No major scale changes in the quantitative composition of the foraminiferal assemblage could be determined throughout the *R. calcarata*interval. Considering the high range of variation, the interpretation of small scale changes in this quantitative dataset is a difficult task to fulfill. However, towards the top of the *R. calcarata* Zone we record an increase in specialist taxa (i.e. globotruncanids) that could be related to changes in the characteristics of the Penninic Ocean (changes in sea level?).

To better assess the foraminiferal record in regards of taxonomic richness in the Austrian Alps, a qualitative analysis was performed. The comparison of data from two sections, the

Postalm and the Oberhehenfeld section, illustrates two slightly different palaeoenvironments that are best assessed over a statistical analysis of benthic foraminiferal data: Postalm section, strictly considered a Cretaceous Oceanic Red Bed, records a stable palaeoenvironment with only few changes in the taxonomic composition. Oberhehenfeld on the other hand depicts instable conditions indicated by frequent changes in the benthic foraminiferal record, particularly in indicative species.

The detailed analysis of a well documented and reliable biostratigraphic interval can give vital insights in mechanisms behind palaeoenvironmental trends as well as short term changes that are sometimes overlooked in the big picture. Presence-absence data can be used as a tool to shed light on differences between palaeocommunities that are easily neglected in standard quantitative data.

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[34] LATE CRETACEOUS MARINE FOSSILS AND SEAWATER INCURSION EVENTS IN THE SONGLIAO BASIN

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The Songliao Basin is the largest non-marine oil-bearing basin in China. However, because of the absence of substantial evidence, the hypothesis of seawater incursion event into the Songliao Basin remains controversial (Gu et al., 1976; Hu et al., 2015). The presence of marine-water fossils could provide direct confirmation of this supposition. The Cretaceous Continental Scientific Drilling project in the Songliao Basin (SK1) offers a unique opportunity to investigate the nature of the non-marine Upper Cretaceous paleoenvironment (Gao et al., 2008). Here, we report new discoveries of foraminifera, nannofossils, dinoflagellates, other marine and brackish-water fossils from SK1 and other well to discuss of the seawater incursion events of the Songliao Basin.

Relatively abundant benthic and planktonic foraminifera, nannofossils, marine and brackish-water algae, fish, and bivalves have been discovered in Members 1 and 2 of the Nenjiang Formation (Xi et al., 2011); a few foraminifera and brackish-water algae have been found in the lower Qingshankou Formation, and just a few brackish-water bivalves have been found in the uppermost Qingshankou Fmormation. Combined with evidence of marine molecular fossils from borehole cores, we suggest that relatively large seawater incursion events occurred during the sedimentation of the lower Nenjiang Fm.; relatively smaller seawater incursions occurred during the deposition of the lower Qingshankou Fm., and possibly a very small seawater incursion occurred during the sedimentation of the uppermost Qingshankou Fm. The seawater incursion events in the Songliao Basin were controlled by regional tectonic activity, evolution of paleo Songliao Lake, and global sea level change. Further, owing to these periodic seawater incursions, marine biota were carried into the Songliao Basin.

Keywords: Cretaceous, Songliao Basin, marine fossils, brackish-water fossil, seawater incursion events, paleoenvironment

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[35] ANALYSIS OF SEA LEVEL CHANGE RECORDS ON THE CRETACEOUS CARBONATE PLATFORMS (ARABIAN AND TAURIDE PLATFORMS TURKEY): COOPERATION OF CLIMATIC AND TECTONIC FACTORS

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In central Taurides, SW Turkey, The Aptian-Cenomanian carbonate successions are composed of cyclic facies. The meter-scale cyclicity starts with subtidal facies including daysclad algal wackestone/packstone, foraminiferal wackestone/packstone/grainstone facies at the bottom and overlain by intertidal birdseye/fenestral limestone, laminar stromatolite facies. The cycles are capped by supratidal stromatolite facies and subaerial features such as mudcracks, dissolution vugs and microkarstic mantling breccias (Yilmaz and Altiner, 2001; 2006)

This cyclic arrangement can easily be traced along the whole measured stratigraphic sections. Penetration depth of the karstification is limited within 1-2 meters. Therefore it is estimated that sea-level changes are short-term and in the order of meter, and not hundreds of meters.

In Taurides, bauxite deposits lying on the "Cenomanian-Turonian" peritidal carbonates and infilling the paleokarstdolines reaching to 150 m in some places are overlain by "Santonian-Campanian" rudist bearing shallow water carbonates.

The bauxite and polygenic conglomerate facies display a tectonically controlled sea level change whereas cyclic meter-scale facies changes are eustatic sea level changes. Tectonically controlled sea level changes display millions of years gap at the exposure surfaces, however eustatic sea level changes present hundred thousands of years gaps at exposure surfaces and generally in meter-scale. They can be interpreted as 4^{th} or 5^{th} order sea level changes.

The third order sea level fall records can be seen as associated with epikarstic breccias taking place on the top of shallowing upward parasequence sets which are generally characterized by frequently alternating exposure surfaces and covered by thicker stromatolites. These breccias can be followed by a change in the pattern of benthic organism's crisis or turn over.

Dolomitization/dolostone levels may coincide with the third order sea level falls and can be correlated along the platform.

In SE Turkey, in the Arabian Platform, the exposed and drilled carbonate successions display cyclic alternation of facies in meter-scale, and laterally may show variations along the Arabian platform.

In the Cenomanian, the studied Derdere Formation displays alternation of benthic foraminiferal, algal packstone/wackestone and bioclastic wackestone/limemudstone at the top and alternation of bivalve wackestone/packstone and limemudstone with planktonic foraminifera or dolomitic limestones/dolostone facies at the bottom. This large-scale (3^{rd}-order) (10s meters) cyclic facies variations from bottom to top in a shallowing upward structure indicate a large-scale control in behind. The small scale (1-2 meters) ($4^{th}/5^{th}$ order) cyclic facies changes display shallowing upward character but incomplete peritidal facies. So small-scale cyclic alternations may represent the effect of climate induced changes superimposed on the large-scale cycles on the Arabian platform.

In Santonian-Maastrichtian interval, in SE Turkey, drowning of the platform carbonates indicates a tectonic control in background related to sudden subsidence. The phosphate deposits related to drowning take place just over the platform carbonates within pelagic/hemi pelagicfacies. Within the Campanian, carbonate successions display alternation of bioclastic packstones/wackestones and chalky facies or alternation of calciturbidites and chalky facies/dolostones in some places. Successions are covered by thick-bedded reefal carbonates including rudists, oestrea, pelecypoda and bryozoa. This larger-scale (100s meters) shallowing upward structure indicates a tectono-sea level change in the studied area.

In SE Turkey, the sequence boundaries around the Cenomanian-Turonian and in the Campanian can be tectonically enhanced and are followed by drowning and covered by pelagic marls and carbonates. These sequence boundaries can also be correlated in nearby countries.

In comparison with Taurides and Arabian platform in Turkey, Cenomanian platform carbonates display differences in facies alternations. In Taurides, shallowing upward facies display more cyclic pattern including changes from subtidal to supratidal, however, In Arabian platform, shallowing upward facies display incomplete cycles, even in same places rhythmic changes.

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[36] CRETACEOUS TWO RAINY SEASONS AND ENSO SIGNALS RECORDED IN NENJIANG FORMATION IN SONGLIAO BASIN

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El Niño-Southern Oscillation (ENSO) is a globally important climate factor，and its Possible changes in the behavior with global warming have provoked interest in records of ENSO from past greenhouse climate states. Late Cretaceous (84Ma) laminated lacustrine mudstone in SongliaoBasin, northeastern China permits an annual scale reconstruction of water column flux events and hence interannualpaleoclimate variability. Seasonal changes of precipitation produced the formation of laminations rich in silt and laminations with more clay. More precipitation or less precipitation resulted in laminations rich in silt or with more clay. Thick silt lamination altering with thin clay lamination shows continuous precipitation with intervals lacking precipitation. No dropstone was found, indicating ice-free winters during this interval in Cretaceous. Time series analysis of the thicknesses of varved sequences indicates strong periodicity in the quasi-biennial (2-year to 3-year) and interannual (4-year to 7-year) bands, which are typical characteristic of modern ENSO forcing, as well as decadal components. The presence of interannual spectral components in Songliao lacustrine sediments, analogous with the interannual behavior of modern ENSO does not support the prediction of increasing frequency of El Nino events with global warming

[37] THE CENOMANIAN-TURONIAN MASS EXTINCTION AND BIOTIC TURNOVER EVENTSIN SOUTHEASTERN TETHYS LINKED TO REDOX CHEMISTRY CHANGES: EVIDENCE FROM MULTIPLE SULFUR ISOTOPES

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The Cenomanian-Turonian (C-T) boundary witnessed one of the eight most severe biotic crises over the past 250 million years (Raup and Sepkoski, 1986). The estimated global extinction rate across the C-T boundary is 7% at the family and 26% at the generic level. Fossil records indicate that the stepwise C-T extinction occurred predominately in intermediate and deep waters and affected numerous marine taxa such as foraminifera, nannofossil, radiolarian, and molluscan. The C-T extinction has been attributed to the expansion of anoxic and euxinic waters during the oceanic anoxic event 2 (OAE2), and this hypothesis has been supported by geochemical and biomarker data from the North Atlantic and western Tethys. However, geochemical data from the southeastern Tethys and the Pacific Ocean suggest oxic oceanic condition for most of the OAE2 interval (Takashima et al., 2011; Bomou et al., 2013). Therefore, global redox chemistry changes in time and space and their potential link to the biotic turnover events remains to be explored.

In this study, we report high-resolution analysis of carbon isotope as well as all four S-isotopic compositions of pyrites from the Gongzha section in South Tibet of China. Our multiple S-isotopic results show that the sulfur isotope signal of $\delta^{34}S$ and$\Delta^{33}S$ changed cyclically in time which may reflect the cyclical fluctuations of the Oxygen Minimum Zone (OMZ). The coincidence of minor S-isotopic anomalies with the biotic turnover events suggests that the expansion and shrinking of the OMZ may have linked to the extinction and biotic turnover events in continental margin area in southeastern Tethys.

Key words: Cenomanian-Turonian; extinction; multiple sulfur isotopes; oceanic anoxic event 2; Tibet

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[38] LATE CRETACEOUS DEPOSITIONAL ENVIRONMENTS ON THE EASTERN RUSSIAN PLATFORM

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In the Late Cretaceous the Russian Platform has been belonging to the North Eastern sector of Peri-Tethys (Baraboshkin et al., 2003). In the Albian-Senomanian the meridional direction of sea extension with a prevalence of siliciclastic sedimentation has been changed to sublatitudinal with mainly carbonate sedimentation. It has been a rebuilding of tectonic structures of the whole area resulting in the termination of the SN sea-strait through the Russian Platform and in the opening of another sea-strait connecting the Russian Platform to the Western Siberia Boreal basin in the East. At the same time the studied basin was joined to the Western Interior Seaway in the West (Baraboshkin et al., 2003).

Due to a high sea level and warm climate of the Late Cretaceous there was extensive accommodation space for sedimentation, so that thick shallow marine deposits, such as chalk, marls, silicites, interbedded by calcareous clays and calcareous zeolitites have been formed.

The Upper Cretaceous chalk deposits, consisting of coccoliths, are found in England, northern France, northern Germany, Denmark, European Russia, Kazakhstan etc. Chalk and marls from the eastern Russian Platform are not easily consolidated, but silicites are usually competent.

Among the fossils the Upper Cretaceous deposits contain sea urchins, belemnites, ammonites, inoceramides and many other bivalves. Moreover, microfauna and microflora are also abundant. Numerous fossils make it easy to determine the chronostratigraphic position of the studied layers and to provide their biostratigraphic correlation with the Geological Time Scale (Olferev, Alekseev, 2003).

The broad investigation of the Upper Cretaceous zeolite-bearing rocks of the Russian Platform for ecological purposes (Zorina et al., 2008) was resulted in an unusual conclusion that significantly supplemented the existing ideas about the genesis of the Upper Cretaceous sedimentary rocks. It was revealed that i) the lithological composition of rocks lacks any correlation with the zeolite content therein; ii) zeolite (clinoptilolite) occurs in all types of carbonate, siliceous, and clayey rocks in the Turonian-Danian lithostratigraphic units of the eastern and southeastern Russian Platform. Hence, the formation of clinoptilolite is related to the diagenetic reworking of the introduced reactive aluminosilicate mineral than the transformation of the initial (parental) rocks, as was previously considered.

A fine pyroclastic material getting into the sea could easily transform to more stable phases as opal-CT, smectite, and clinoptilolite, promoting formation of silicites, smectite-bearing clays, and zeolitites, respectively. The paragenesis of authigenic minerals (opal-CT, smectite, clinoptilolite) in association with semi-decomposed fragments of volcanic glasses was identified as «disguised» pyroclastics. The pyroclastic material was likely supplied by the Black Sea volcanic arc that has been actively functioning in the Cretaceous (Nikishin et al., 2013).

Quantitative changes of the clinoptilolite content in the lithostratigraphic units correlating with the General Stratigraphic Scale reflect variations in the intensity of volcanic activity in the Late Cretaceous (Zorina et al., 2008). The delivery of volcaniclastic material was sufficiently intense in the Turonian-Coniacian (up to 13%). The volcanic activity was likely most intense in the Santonian. Precisely, the Santonian sediments are characterized by steadily high clinoptilolite concentrations (16–28%). Input of the volcaniclastic material was substantially lower in the Campanian. Marly and chalky rocks are characterized by a small but steady content of clinoptilolite (8–9%). The clinoptilolite distribution is irregular (0–16%) in the Maastrichtian chalks and marls, and it is appreciably lower in the Danian beds (up to 15%).

However, lower intensity of clinoptilolite formation in the Danian does not indicate attenuation of volcanic activity. Intense volcanism in the Danian is suggested by thick silicites that are widespread on the eastern Russian Platform (Zorina et al., 2008). The lower clinoptilolite concentration in the Paleocene, as compared to the Santonian, is related to a different (less alkaline) composition of the Danian pyroclastic material moving from the volcanic arc of the Lesser Caucasus to the North and scattering over a vast area of the Russian Platform.

The results obtained support conclusions about the primary volcanogenic nature of the clinoptilolite-forming material that was delivered as pyroclastic material to the sedimentary basin. Variations in clinoptilolite contents in the Turonian-Maastrichtian lithostratigraphic units can be caused by changes in the intensity of volcanic activity.

In summary, the undertaken studies have shown that the conclusions about depositional environments in the Russian Platform in the Late Cretaceous and Paleocene should necessarily take into account the influence of volcanic activity of different intensity, because the «disguised» pyroclastics compose the greater part of the Upper Cretaceous and almost all the Paleogene rocks in the Eastern Russian platform.

Key words: Late Cretaceous, Russian Platform, carbonate sedimentation, volcaniclastic material

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