EUG XI

Theme CC

Climate Change

EUG XI

Symposium CC01

Neogene Environments: Case Studies for Potential Future Greenhouse Climates

Convenor

Peter Smolka

Sunday PO Session

CC01 : SUpo01 : PO
Contribution of Carbonate Continental Geochemistry to the Climatic and Palaeoenvironmental Reconstitution of the Namib Desert

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The Namib desert is the oldest known on earth. It formed approximately 15 to 16 million years ago in relation with three processes : (1) formation of the Antarctic Ice sheet, which reinforced the belt of high atmospheric pressures under the Tropic of Capricorn; (2) initiation of the cold Benguela oceanic current along the west coast of Africa; (3) Namibian oceanic upwelling episodes. Namibia is therefore primordial in reconstructing the palaeoenvironmental of the Southern Hemisphere since the Miocene. Because of the important interactions between the Atlantic Ocean and the Namib, the area is a focal point for the study of the continent-ocean system and of the geochimical exchanges between these two ecosystems. This study integrates the geochimical markers of climatic evolution - trace elements, stables isotopes of carbon and oxygen - to sedimentological analysis (aeolianites) and to palaeontological analysis (rodents and ratites). This will be accomplished in a reliable chronostratigraphic framework (calibrated using eggs of ratite and mammals). Preliminary results : $\delta^{13}C$ on eggshells of ratites show a similar evolution for species from the diamantiferous zone (Oranjemund, 28°S) and from the Namib-Naukluft Park to the North (22°S). The $\delta^{13}C$ evolution trend decrease at 12/14 Ma (-9‰ to -11‰), during the Middle/Upper Miocene the $\delta^{13}C$= -11‰ and at 6/8 Ma the $\delta^{13}C$ is on the increase (-9.5‰ during the Pliocene and -5‰ for the Recent). This isotopic signal variations seem to reflect : (1) a change in the mode of feeding associated (variations in C4/C3 ratio), (2) with the climatic fluctuation in relation with the Antarctic Ice sheet variations. Our preliminary results show a good correlation between the $\delta^{13}C$ evolution trend from Middle Miocene ratite eggs and the well-known oceanic isotopic curves. The isotopic signal variations on eggshells seems to indicate a less arid period for the Middle and Upper Miocene, in agreement with the sedimentological data (palaesols and roots remains associated with the eggshells of ratites) The trace elements provide evidence of the environmental effect: for instance, an increase in Na is observed from inland to Atlantic Ocean. This study leads to: (1) a better understanding of the regional climatic fluctuations; (2) enhanced chronostratigraphic correlations between the Ocean and the Continent.

CC01 : SUpo02 : PO
The Influence of the Degree of the Continentality of the Climate on Climatic Characteristics of most Warm Late Pleistocene $^{16}O/^{18}O$ Substage 5 Year (Latitude Profile: Carpathians-Caucasus-Altai)

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There are hundreds of pollen diagrams of large Pleistocene isotope $^{16}O/^{18}O$ stage interglacial in the Eastern and Western Europe and Siberia, but only few of them is possible to correlate it correctly with the most warm interval of the isotope stage 5 - substage 5e. Now there are some pollen diagrams for the sections from the former USSR territory that belong to the sediments with palaeomagnetic episode Blake and have three optima of $^{16}O/^{18}O$ stage 5 (including substage 5e) The data on some sections of the Transcarpathia, the North-West Caucasus and the Norh-West Altai and on some plain areas are discussed in the report. They allow to compare the influence of the digree of the continentality of climate on the climatic characteristics of the last warmest climatic stage of the Pleistocene in the middle part of Eurasia.

The author is grateful to the Russian Human Research Foundation for the grants 98-01-00425 and 98-01-00313a that allowed to compare palynological data on different areas of the former USSR territory.

CC01 : SUpo03 : PO
Miocene Lateritization in Western France Rb-Sr Geochronology and $\delta^{18}O$ - δD Paleothermometry

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The Miocene epoch, ranging in age from 23 Ma to 5 Ma, constitutes a key period for the history of the earth's climate. Miocene is known to be a time during which the global climate was significantly warmer than today, in particular at mid-latitudes such as Western Europe. However, within Miocene times, the global climate became increasingly cooler. This was related to the inception of a modern-like circum-polar ocean circulation, resulting in the development of larger polar ice caps. As a consequence, the study of the geological markers of climatic changes during this epoch is of premium importance.

A lateritic paleosoil is described, located in the Fouilloux forest, near the town of Saint-Maixent (Western France). On the basis of stratigraphic correlations, this lateritic formation, which overlies Cenozoic lacustrine limestones is presently interpreted as being of Miocene age. Geological field evidences indicate that the paleosoil developed directly in situ over the limestones. This lateritic formation is approximately 10 meters thick, and does not show any evidence of duricrust development. Fe-pisolites are very abundant. Two types have been distinguished morphologically: (1) almost perfectly spherical pisolites, no greater than a few millimeters in diameter, (2) irregular pisolites with sizes on the order of one centimeter or more. On the assumtion that a duricrust did form during paleopedogenesis, pisolites (1) can be possibly linked to the build-up of the lateritic duricrust, whereas pisolites (2) could be related to its destruction.

The two populations of pisolites are studied by the Rb-Sr isotopic chronometer, in attempt to date precisely this lateritic paleopedogenesis episode. In addition, stable isotopic studies ($\delta^{18}O$ - δD) are carried out to constrain paleoclimatic parameters, especially paleotemperatures, at the time of emplacement of this lateritic paleosoil. Stable isotope as well as radiochronological data will be presented and discussed.

CC01 : SUpo04 : PO
Late Neogene Eolian Deposition in Southern Tarim Basin and its Palaeoenvironmental Significance

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Uplift of the Tibetan Plateau during the late Cenozoic resulted in an apron of thick molassic sediments along the northern piedmonts of the Kunlun and Altyn Mountains in the southern Tarim Basin. Early Neogene sediments are characterised by red-coloured mudstone, siltstone and sandstone, representing floodplain to distal alluvial fan environments. These pass upwards into thinly bedded red-coloured mudstone and very fine-grained siltstone, with bedded gypsum towards the Mio-Pliocene boundary. The Early Pliocene Artux Formation consists of medium-grained sandstone and sandy mudstone, with thin layers of fine gravel. Late Pliocene to early Pleistocene Xiyu Formation is dominated by pebble to boulder conglomerate typical of alluvial-fan debris flow deposits. There are numerous bands or lens of siltstone intercalated with sandstone or conglomerate in the Xiyu and Artux Formations. Sedimentological investigation and chemical analysis, together with field observations point to an aeolian origin for these intercalated siltstone bands, suggesting that the Tarim basin had become an desert area by the early Pliocene, if not earlier. The Taklimakan Desert may therefore have existed in the early Pliocene, and, by inference, there was a similar climatic regime to that of today established by then. The onset of aeolian sedimentation in the southern Tarim basin coincided with the lithofacies shift from fine-grained mudstone and sandstone to coarse clastic rocks approximately 4.5 million years ago (Zheng et al., 2000). Uplift of the Tibetan Plateau resulted in the shift of sedimentary environments in the southern Tarim, and may have well triggered the onset of full aridity in the region as a whole.

Zheng H, Powell CMcA, An ZS, Zhou J & Dong GG, *Geology*, **28**, 715-718, (2000).

Monday PM Session

CC01 : MOpm21 : G1
Reconstructing and Modeling Neogene Environments: Selected Results and Future Perspectives

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The Neogene is a time that is characterized by environmental conditions that may serve as example for future greenhouse conditions. Therefore time-scales and magnitudes of Neogene environmental change have been studied. This includes such as long-ranging time-series of sea-surface temperatures, the history of faunal developments and the study of inherent properties (characteristical oscillations and patterns) preceding a regional change, their synchronization to maps (10 time-intervals) and, to assess the non reconstructable parameters such as moisture distribution in the air, the subsequent coupling of the reconstructed Neogene oceans with a global atmospheric circulation model (at T42 resolution).

It could be shown that the known present-day surface circulation existed, with modifications and especially changes of intensity, throughout the entire Neogene. Of special importance is the indirect effect of the closure of the Isthmus of Panama, that, most likely through the deep circulation, impacts also sites between Australia and New Zealand (baseline-shift of temperature characteristics). Another fundamental shift of temperatures occurs in many places of the world around 2.6 my. Of special importance are however regional temperature fluctuations at watermass-boundaries.

The coupling of the results with an atmospheric general circulation model showed moisture distributions that differed from present-day situations. Data, maps and models are published in Smolka and Volkheimer (2000).

Taking (a) the considerable magnitude of environmental fluctuations that had been observed, that exceeds any discussed man-made effect by far and (b) considering (through modeling) also the impacts of such changes on land, even if the effects are regionally and not global, the consequence to be drawn is that any disturbance of the present-day climatic equilibrium should be avoided, simply to prevent an unintended triggering of a natural fluctuation.

Future work can thus focus on (a) increased data densities both marine and terrestrial, coupling of reconstructions and atmospheric general circulation models to arrive at sets of maps of potential situations, (b) studies of the mechanisms before a change (quantitative assessment of fractions of chaotic, linear and periodical components in a time-series) to assess conditions preceding a change, (c) the application of neural network studies to predict one part of a time-series from the preceding section(s). A still not fully utilized but possible future perspective is the formulation of fluxes such as precipitation, CO_2, ice-builtup in terms of box models with a seasonal resolution (integrating both physical processes, heuristics and numerical solutions) in terms of a worldwide gridded model.

Smolka PP, Volkheimer W, *Southern Hemisphere Paleo- and Neoclimates. Key Sites, Methods, Data and Models. Springer Science Publihshers (with CD-ROM)*, 381pp., (2000).

CC01 : MOpm22 : G1
Deciphering Global and Regional Impacts of Long-term Changes in the Carbon Cycle in the Upwelling System off SW Africa

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Quantitative temperature reconstructions for the Pliocene-Pleistocene cooling transition are needed to understand the processes that have caused Earth's climate to enter the Glacial-Interglacial quasi-stable state but have thus far been limited by shortcomings in the proxy techniques used. Most reconstructions are difficult to interpret quantitatively because species extinctions during the late Pliocene and Pleistocene mean that contiguous modern analogous assemblages do not exist. We have adopted a relatively novel approach to reconstruct Neogene sea surface temperatures using the UK37' index. The UK37' index is based on the ratio of di- and tri-unsaturated n-C37 alkenones produced by specific species of Haptophyceae algae (Brassell et al., 1986). Chemotaxonomic and early/pre-Quaternary studies suggest that UK37' does not appear to be affected by either Pliocene-Pleistocene species extinctions or variations in production depth, nutrients, and seasonal production maxima.

In a recent paper we showed that in the Benguela Current upwelling system off SW Africa, sea surface temperatures (based on UK37') have declined by about 10ºC since 3.2 Ma (Ocean Drilling Program Site 1084; Marlow et al., 2000). Further analysis of UK37' in two additional sites off SW Africa spanning several million years allow us to appraise the magnitude of the global and regional components of the long-term cooling trends. Records of paleoproductivity suggest that the regional component of the cooling is associated with an increase in wind-driven upwelling tied to a shift from relatively stable global warmth during the mid-Pliocene to the high amplitude glacial-interglacial cycles of the late Quaternary. This is in agreement with previous records of aeolian dust flux to marine sediments that suggested increased trade-wind strength and aridification of Africa throughout the cooling transition. This increase in atmospheric circulation would have been driven by a steeper pole-equator temperature gradient owing to the development of the bipolar cryosphere. Enhanced upwelling may have also occurred at the eastern boundaries of the other three major Atlantic and Pacific Ocean basins.

We have also used another molecular technique to gain insights into long-term changes in the carbon cycle at the ocean-atmosphere interface of the Benguela Current upwelling system. This proxy is based on the measurement of d13C in the same n-C37 alkenones used to reconstruct SST. The $\delta^{13}C$ of the alkenones has the potential to provide a proxy for changes in the dissolved fugacity of CO_2 in the upwelling system over the past 4.5 million years. Or results show that the alkenone record gradually became isotopically lighter throughout the Pliocene-Pleistocene. We believe that this is a regional influence on the $\delta^{13}C$ signal owing to the gradual enhancement of upwelling, which in turn enhanced the long-term (100 ky) "leak" of CO_2 from the global ocean-atmosphere system as sedimentary organic carbon.

Brassell SC, Eglinton G., Pflaumann U. & Sarnthein M, *Nature*, **320**, 129-133, (1986).
Marlow JR, Lange CB, Wefer G & Rosell-Mele A, *Science*, in press, (2000).

CC01 : MOpm23 : G1
The Middle-Late Miocene "Carbonate Crash" and "Biogenic Bloom" in the Cape Basin of the South Atlantic Ocean (ODP Sites 1085 and 1087)

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The combination of major plate tectonic rearrangements and planetary cooling during the middle-to-late Miocene led to establishment of present-day oceanic circulation and in particular the North Atlantic Deep Water flow (NADW). Global sedimentation patterns responded to these oceanographic changes. In the equatorial regions of the Indian and Pacific Oceans and in the Caribbean, several episodes with significant drops in concentrations and mass accumulation rates of $CaCO_3$ occurred between 13 and 9.5 Ma (the middle-late Miocene "carbonate crash") and are followed by a strong increase in biogenous sedimentation begining about 7 Ma (the late Miocene "biogenic bloom").

The carbonate crash is coincident with the shift of opal deposition from the Atlantic to the Pacific (the "silica switch"), which is attributed to the onset of NADW-dominated deep circulation. No convincing explanations for the carbonate crash have been given. Sediments from ODP Sites 1085 and 1087, at 1700 and 1400 m water depth respectively in the Cape Basin, exhibit major drops in carbonate concentrations at 9.5-9.0 Ma that are synchronous with the carbonate crash in the East Pacific (Lyle et al.,1995).This event off SW Africa is preceded by major increases in delivery of terrigenous sediments and in the proportion of kaolinite (Paturel, 2000) and an expansion of the oxygen minimum zone. After the low-carbonate period, oxygenation of bottom waters was high from 9.0-6.5 Ma, presumably because of the presence of NADW-related water masses. However, productivity remained quite low until 6.5 Ma, when an increase in benthic foraminifera and enhanced organic carbon accumulation rates indicate a 3-6 fold increase in marine productivity. The onset of high productivity off SW Africa is simultaneous to that in the equatorial East Pacific and to an increase in carbonate accumulation rates in the equatorial West Pacific and Indian Oceans. A strengthening of latitudinal temperature gradients, and corresponding vertical mixing by zonal winds in the oceans is postulated to be responsible for the global biogenic bloom at 6.5 Ma. Reasons for the carbonate crash itself remain obscure but must be sought in unusual processes related to the transition of the ocean-atmosphere system from a "warm" state with low productivity to a "cold" state with vigorous deep ventilation and emerging upwelling regimes.

Paturel J, *Memoire de DEA, Univ.de la Mediterranee Aix-MArseille II*, 44 pp, (2000).
Lyle M, Dadey KA, Farrell JW, *Proc.ODP, Sc.Res 138*, **138**, 821-838, (1995).

CC01 : MOpm24 : G1
Why was the Atmospheric CO_2 Level Low during the Miocene?- An Investigation with a Box-Model of the Carbon Cycle

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Recently, paleolevels of atmospheric CO_2 at various times during the Cenozoic have been reconstructed from several types of proxy records, such as the ^{13}C isotopic composition of marine organic matter (Pagani et al., 1999) or the seawater pH recorded in boron isotopes (Pearson and Palmer, 2000). These records suggest that the partial pressure of atmospheric CO_2 $P(CO_2)$ was high during the Paleocene and Eocene, decreased during the Oligocene to reach values smaller than today during the Miocene and finally increased up again to approximately the pre-industrial value during the Pliocene. Box-models of the long term carbon cycle consistently predict high levels of CO_2 during early Cenozoic times, but these models generally produce a monotonic decrease of $P(CO_2)$ from the Eocene to the present and thus fail to yield Miocene CO_2 levels lower than today. We present here a model which is able to

reproduce a minimum of atmospheric $P(CO_2)$ in the Miocene. Contrary to most earlier box-models of the long term carbon cycle, this model splits the crustal carbonate reservoir into its oceanic (pelagic carbonates) and continental (shelf carbonates) components. Only part of the carbon released by the decarbonation of the pelagic reservoir (following subduction of the oceanic crust) returns to the atmosphere through arc-volcanism, the rest being transferred to the mantle. Preliminary experiments performed with this model suggest that $P(CO_2)$ was high during early Cenozoic times, not because of higher volcanic fluxes, but in response to several other factors. One of these factors was the predominance of shallow versus deep water carbonate deposition at that time. As the locus of carbonate deposition is progressively transferred to the pelagic environment, atmospheric $P(CO_2)$ decreases and reaches a minimum in the Miocene consistently with the proxy data. The shift of carbonate deposition to the pelagic environment is also accompanied by a sharp rise in the size of the pelagic carbonate reservoir, followed by an increase of CO_2 release from arc-volcanism. This latter volcanic increase is responsible for the slight increase of $P(CO_2)$ in post-Miocene times. This recent increasing trend of $P(CO_2)$ was reinforced by simultaneous changes in the organic subcycle.

Pagani M., Freeman K.H. & Arthur M.A., *Science*, **285**, 876-897, (1999).
Pearson P.N. & Palmer M.R, *Nature*, **406**, 695-699, (2000).

CC01 : MOpm25 : G1
Magnetostratigraphic Record of the Late Miocene Onset of the East Asia Monsoon, and Pliocene Uplift of Northern Tibet

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Widespread eolian red clay underlying the Plio-Pleistocene loess-paleosol succession in Northern China has been dated magnetostratigraphically back to 8.35 Ma, indicating that the East Asia monsoon started at about the same time as the Indian Ocean monsoon. Initial sedimentation rates of 11 m/Myr increased gradually to 17.5 m/Myr by 6 Ma, and then decreased to 6 m/Myr between 5 Ma and 3.5 Ma. A marked increase in sedimentation rate and grain size beginning between 3.5 Ma and 3.1 Ma, indicates that the East Asia winter monsoon strengthened at this time, and intensified further after 2.6 Ma. A magnetostratigraphically-controlled study of Neogene deposits on the piedmont of the NW Kun Lun mountains shows that fine-grained sandstone, and red siltstone and claystone, were deposited throughout the Miocene up to the earliest Pliocene (Zheng et al., 2000). Commencing in the Early Pliocene, increasingly coarse detritus were deposited in debris flows containing boulders greater than 2 m in diameter. Sedimentation rates increased from an average 0.15 mm per year for the Oligocene and Miocene to 1.4 mm per year during the Gauss normal chron (3.6-2.6 Ma), and reflect the Early Pliocene rise of the NW margin of Tibet. The temporal coincidence of the stronger winter monsoon and the Pliocene uplift of northwestern Tibet just before the onset of the Northern Hemisphere glaciation indicates that the three events could be causally linked.

Zheng HB, Powell CMcA, An ZS, Zhou J & Dong GG, *Geology*, **28**, 715-718, (2000).

CC01 : MOpm28 : G1
Dynamics of Zonality and Climate in Northern Eurasia during Warm Neogene Epochs and Quaternary Interglacials

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At the Miocene climatic optimum (about 20 to 15 Ma BP) a vast forest zone dominated over Northern Eurasia between 75 and 45°N; the forests consisted primarily of species currently found in temperate, mild temperate and subtropical environments. On the whole, the zonality was not unlike to the "thermo-hyperzonality" typical of this area during the Paleogene.

By the Pliocene climatic optimum (approximately 4 Ma BP) a polyzonal landscape structure was fully developed; forest-steppe and steppe landscapes appeared in the region south of the forests. Further development of the polyzonal structure takes place during the Quaternary interglacial epochs. Steppe and desert area expanded in the south, with tundra and forest tundra existing in the north. A general trend towards cooling resulted in that the cryolithozone was permanently present in the north of Europe since 400 ka BP, even during interglacials. On the whole, the optima of warm intervals tend to become progressively cooler from the Neogene towards Quaternary.

CC01 : MOpm29 : G1
Terrestrial Paleotemperature Calculations from the Praetiglian/Tiglian (Plio-Pleistocene) Pollen Record of Lieth, Northern Germany: Implications for the Climatic Evolution of NW Europe

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On a global scale, paleoclimate reconstructions for the younger Neogene and Pleistocene are substantially based on proxy data from the marine realm. The paleoclimate history of the continents is, in comparison, less well established although terrestrial paleoclimate records are indispensable for gaining a comprehensive view of global changes. Hence, in order to obtain quantitative paleoclimate information for the Plio-Pleistocene of NW Europe, we reconstructed the temperature evolution from the Praetiglian and Tiglian pollen record from Lieth, northern Germany. The examined record covers the time span from approximately 2.6 to 1.7 Ma. Calculations of the temperatures of the warmest (MTW) and coldest (MTC) months are presented utilizing the mutual climatic range principle. The thermal resolution of the reconstruction is increased through the calculation of most likely intervals for actual temperatures ranges. For the analyzed pollen record, the MTW and MTC resolution reaches up to 1.5°C using 100% most likely intervals and up to 1°C using 70% most likely intervals. A seasonality index is calculated as a further tool for evaluating the climate development. The results indicate that cold and temperate stages during the Praetiglian and Tiglian were characterized by strong variations in winter temperatures in combination with relatively constant summer temperatures. Seasonality was highest during cold stages and lowest during the thermal optima of temperate stages. These seasonality variations are attributed to sea level changes as expressed in the North Sea Basin as well as to changes in North Atlantic Ocean circulation and the position of the oceanic polar front. The comparison of temperature calculations from Lieth with pollen-based estimates for corresponding time intervals from the Netherlands as available in the literature yields similarities and differences. For cold periods, the quantitatively obtained temperatures from Lieth are generally more extreme than the estimates from the Netherlands. These contrasts are too high to result solely from differences in the evaluation methods as can be shown through the application of our quantitative approach to pollen spectra from the Netherlands. Moreover, the MTC reconstructions from Lieth are in good agreement with winter temperatures derived from time-equivalent periglacial features in northern Belgium. Hence, the inferred temperature differences may indicate a temporary climate differentiation between these regions during cooler periods of the Praetiglian and Tiglian that may be related to the respective proximities of these regions to the North Sea.

CC01 : MOpm30 : G1
Miocene Records of Climate Change from Shark Teeth and Ostracods of the North Alpine Molasse Sediments

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The molasse sediments of southern Germany, Austria, and Slovakia were deposited during the Early to Late Miocene. This period is characterized by significant global change in oceanography and climate but also by a change in the regional paleogeography because of the ongoing Alpine orogeny. To address the influence of the Alpine orogeny on the regional climate and oceanography of the molasse basins to the north and east of the Alps, the chemical and isotopic composition of fossil shark teeth and ostracods are investigated.

Paleoecological evidence, Sr/Ca ratios, Sr-isotope compositions of fossil ostracods and shark teeth, as well as the O-isotope composition of phosphate in shark teeth and mammalian fossils (dolphin teeth and seacow ribs) from the same horizon, support an open marine environment for the Lower to Middle Miocene. Brackish conditions can be inferred for the Middle to Upper Miocene samples of the molasse. This implies that the oxygen isotope composition of the Lower to Middle Miocene samples can be used for paleoclimatic interpretations of the northern Paratethys sea.

The O-isotope compositions of fossil ostracods and shark teeth vary in parallel with time. However, changes in the O-isotopes composition of the ostracods are much more pronounced compared to those of the shark teeth. This could be related to the ecology of the species. The ostracods analyzed (*Cytheridea* spp., *Cyprideis* spp.) are restricted to occur in coastal regions in a fairly narrow habitat. In contrast, the shark teeth analyzed were largely restricted to the genus *Carcharias*, which by comparison to recent sharks is very much a migratory species. Comparison of the oxygen isotope data for ostracods and shark teeth with those reported for planktonic and benthic foraminifera from the North Atlantic and the Mediterranean Tethys, shows agreement in the overall trend between 20 to 14 Ma, indicating a parallel climatic evolution. In terms of the Nd-isotope compositions of ostracods and shark teeth no major change in ocean circulation can be recognized for the northern Paratethys with time. The Nd-isotope compositions are generally similar to those measured for samples from the North Atlantic. For samples younger than 14 Ma, O- and C-isotope compositions of ostracods show large fluctuations, indicating variable freshwater influence. This complicates a direct comparison of regional with global changes in climate. However, temperature changes deduced by a comparison of O-isotope compositions, Sr/Ca, and Mg/Ca ratios for the period from 12 to 8 Ma do not correspond to changes in global temperature, and may hint at a regional Alpine influence on climate.

CC01 : MOpm31 : G1
Global Climatic and Environmental Events throughout the Late Neogene Time (5.5-1.2 Ma Ago)

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The modern empirical data allow revealing a few stages in changing in the Pliocene environmental and climate: · A warming in the Early and in the beginning of the Late Pliocene (4.3-3.3 Ma ago) accompanied with doubling CO_2 concentration in the atmosphere as compared with its modern value. This interval is characterized by a 3.6°C global temperature increase, a 20-25°C air temperature rise in the high latitude in winter and a 6-8°C rise in summer, and a considering improvement of moisture conditions at all latitudes, in particular, in the interior (presently arid and semiarid) regions of Asia and Africa, the degradation of the Antarctic ice sheet and ice-free regime in Arctic. Presented are the map-reconstructions of the summer and winter temperature and annual sums of precipitation for this warm interval of the Early Pliocene; · The first stage of global cooling about 3.2-3.0 Ma ago accompanied with a considerable extinction of heat-loving species of land plants in Europe and increasing the aridity in the interior regions of Asia and Africa. The first appearance of permafrost in the

north-eastern part of Asia and the first sheet glaciation in Greenland and Iceland; · The second stage of global cooling about 2.5 Ma ago coinciding with the full disappearance of heat-loving species from Europe, the formation of true tundra cenoses in the north and the north-eastern of Russia and Alaska, the first sheet glaciation of North America, mountain glaciation in the Alps and drastic lowering of sea level; · A global climate warming and "ice-free" Arctic, about 1.7-1.6 Ma ago, accompanied with ice melt in the northern hemisphere and appearance of "taiga" vegetation in the north of Greenland, improving moisture conditions in the southern part of the Ukraine (the last soils of savannah-type) in the Black Sea region, the Central Asia and Kazakhstan; · A drastic climate cooling about 1.1-1.0 Ma ago, the Euboronian-Menapian stage in the environmental in west Europe and the onset of climate variations of the "Pleistocene type" in northern hemisphere.

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The Influence of Vegetation on the Climate System of the Tortonian (Late Miocene): Results from Climate Modelling

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In a sensitivity study the impact of the vegetation on the Earth's climate system during the Tortonian (Late Miocene, 8 Ma) is examined. An earlier study had shown that atmospheric conditions during the Tortonian differ strongly from recent climate. In that study, the Atmospheric General Circulation Model (AGCM) ECHAM4 was used with a mixed-layer ocean, a supposed Tortonian orography (which was in general less pronounced than today), and an open Panamanian Isthmus. The vegetation was assumed to follow the recent distribution pattern. In the present study, the boundary layer conditions for the ECHAM4 vegetation are selected such that they are in accordance with Tortonian conditions. A biome model is used to classify the vegetation types. The input vegetation distribution for the Tortonian is based on proxy data and, if no proxy data are available, on data from the biome model as established in the previous study. With respect to the previous study, changed boundary layer conditions for the AGCM include albedo, leaf area index, forest cover, vegetation cover, and maximum available soil water content. All other conditions remain unchanged. The results show that the vegetation distribution has a strong influence on the climate system. The most descriptive example is the temperature field which shows a decrease in seasonality but with an increased warmth. The summer temperatures of both hemispheres are about 0.5°C higher than in the previous study, whereas the winter temperatures become much higher (0.6°C in the South, 15°C in the North). The seasonality of both hemispheres is reduced, with the northern hemisphere being more affected than the southern. The mean annual temperature of Central Europe (parts of Germany and France) ranges from 9 to 15°C, with winter temperatures between 3 and 9°C and summer temperatures between 15 and 21°C. For Spain the mean annual temperature rises up to 18-21°C and for winter and summer up to 9-15°C and 24-33°C, respectively. The biome distribution derived from the performed runs are compared to the Tortonian vegetation as used as input data. Based on these comparisons changes in temperature and precipitation are described and model data are evaluated.