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Vortragsabstracts

MARINOAN GLACIAL AND POSTGLACIAL SUCCESSIONS AT THE SOUTHERN RIFTED MARGIN OF THE CONGO CRATON (NEOPROTEROZOIC, NORTHERN NAMIBIA): FACIES, PALAEOGEOGRAPHY AND HYDROCARBON PERSPECTIVE

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In northern Namibia continental rifting occurred at about 750 Ma (Nosib Group). It is followed in the late Neoproterozoic by the deposition of predominantly shallow-water platform carbonates (Otavi Group). These are up to 5000 metres thick, and were deposited on the southern "passive" margin of the Congo craton. The Otavi Group is exposed in a fold belt from the Kaokoveld in the West to the Otavi Mountainland (OML) in the East. Deposition occurred at sub-tropical to tropical latitudes, although at that time climate might have been partly colder in the tropics than today. The Otavi Group is thought to represent a time span of around 200 million years. A complex palaeogeographic setting with small, restricted basins occurred. Frequent submarine mass movements with a wide variety of clasts derived from the underlying Otavi and Nosib Groups, suggest repeated uplift of partly several thousands of metres and deep erosion of the former carbonate platform/ramp.

Two discrete glaciogenic units are known in the Neoproterozoic of northern Namibia. The older one (Chuos Fm.) occurred during the Nosib rifting episode, the younger one (Ghaub Formation, zircon dating of associated tuffs: 635.5 ± 1.2 Ma) is intercalated in the middle part of the Otavi Group. Ghaub diamictites often reach considerable thickness (>100m) and are restricted to slope settings. Different intervals of diamictite sheddings (from approximately East to West) have been outlined in the central OML. The clasts consist mostly of reworked Otavi and Nosib sediments; only a minor percentage is derived from local crystalline basement. Diamictites seem to be lacking on top of the shallower parts of the carbonate ramp, an argument against "grounded ice". As the assumed glaciers cannot transport the basement clasts for thousands of metres upwards, uplift of large areas that became glaciated is a likely scenario, largely corresponding to the one given by Eyles and Januszczak (2004) (Zipper-Rift-Earth). Most of the diamictites represent debris flows, and no prominent striations occur on the clasts. The only valid argument for glaciations at that time is given by a few dropstones at the base of the overlying postglacial interval.

The post-glacial cap carbonate sequence (Maieberg Fm.) is much more widely developed than the Ghaub Fm. The succession consists of a lower part, up to about ten metres thick of often laminated, micritic Cap Dolomite. As in many other parts of the world, where possibly contemporaneous glacial intervals have been found (e.g. Southwest Namibia, Central Australia, Mackenzie Mts. in Canada, East Greenland and East Svalbard Caledonides) a shaly-marly interval overlies the Cap Dolomites and forms the middle and upper part of the cap carbonate sequence. During this interval, the climate might have distinctly improved.

As in the other areas mentioned, the cap carbonate sequence above the buff coloured Cap Dolomites changes in colour from brown to grey and/or black. It is often rich in pyrite (distributed within the sediment in small aggregates but also filling veins), if the Ghaub diamictite is present in the underlying rocks. This marly-shaly succession is locally more than 200 m thick and contains organic-rich intervals, potential hydrocarbon source rocks. Strong thickness differences indicate, that the shaly succession partly fills the preexisting slope and basin settings. In the central OML, the Maieberg Fm. distinctly increases in thickness westward, from 70 m to 230 m, in line with the westward thickening of the diamictites. Debris flows and turbidite intervals several metres thick are intercalated within the marls.

Two types of organofacies have been found: Type 1 is dominated by strongly degraded acritarchs and is oil prone, typical for lighter, medium grey rocks. Type 2 contains inertinite dominated kerogen with few degraded acritarchs and AOM, typical for dark grey to black rocks. The latter type represents higher anoxic levels. Fluid inclusions and thermoluminescence indicate short lived higher temperatures (150 to 200°C, hydrothermal pulses related with ore emplacements) than the ones indicated by the organic material. The degree of maturation might fluctuate laterally. The described setting shows a potential for hydrocarbons, especially "tight gas" further to the north, in the Owambo Basin.

MULTI-PHASE POROSITY-PRESERVING CHLORITE CEMENTATION IN SHALLOW MARINE VOLCANO-CLASTIC SANDSTONES, SAWAN GAS FIELD, PAKISTAN

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Sandstones with anomalously high porosity and permeability at great burial depth and high temperatures are of economic importance, as a significant amount of hydrocarbons have been discovered in these reservoirs. The Sawan gas field lies 500 km northeast of Karachi, in the Middle Indus Basin. The reservoir rocks, Cretaceous volcanoclastic sandstones (Albian-Cenomanian) of the Lower Goru Formation, show anomalously high porosities (20%) at depths of 3000 to 3500 m.

The sandstones are subarkoses to lithic arkoses and sublitharenites to feldspathic litharenites. Strongly altered volcanic rock fragments are the most important lithic component. The clay fraction (<2 mm) consists of Fe-rich chlorite (chamosite) and illite. Diagenetic features such as compaction, quartz overgrowth cements, carbonate- and chlorite cements and feldspar dissolution can be observed.

Authigenic chlorite occurs as two-phase pore lining cement, pore filling cement and chloritized detrital components, all having similar chemical compositions. The pore lining cement, comprising a 5–10 mm thick rim covering all detrital grains, clearly developed in two generations; an older, poorly crystallized and a younger better crystallized growth. The latter comprises euhedral, pseudohexagonal crystals, oriented with their faces perpendicular to the host detrital grain surface. Rim precipitation occurred after an initial stage of compaction but early relative to other diagenetic phases. Both chlorite rim generations grew by direct precipitation from pore waters, using products derived from volcanic rock fragments. In areas with no, thin, or discontinuous chlorite rims, quartz cementation is common. Well-developed chlorite rims inhibited quartz cementation, preserved anomalously high porosities and permeabilities, but did not inhibit carbonate cementation.

The restriction of the porosity preserving diagenetic processes to sandstones deposited in a very shallow marine environment with occasional influx of meteoric water provides evidence for a primary depositional control during the burial process and could indicate an eogenetic chlorite precursor phase.

THREE DIMENSIONAL GROUND-PENETRATING RADAR ANALYSIS OF ALLUVIAL FAN DEPOSITS (DEATH VALLEY, SW USA)

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Altough the number of scientific papers on depositional units of alluvial fans is growing, only little is known about the subsurface stacking pattern of these architectural elements. This study wants to test the utility of ground-penetrating radar (GPR) in three dimensionally imaging of alluvial fans, a landform that has had little attention by GPR users.

The study combines high-resolution, high-frequency GPR surveys with sedimentological studies at the cutfaces of incised channels. Using scaled 2D outcrop photo mosaics we quantitatively analysed lithofacies and architectural elements. Architectural elements are grouped to higher-order depositional systems (e.g. braided-fluvial system or mass flows) and the prevailing depositional processes. The delineated depositional systems, which are separated by bounding surfaces, can be recognized in the outcrops. Depositional packages have been interpreted according to the morphometric base-level concept.

So far four alluvial fans (Trail Canyon Fan, Hanaupah Canyon Fan, Warm Spring and Anvil Spring Fan) have been investigated. The depositional record of all three fans shows overall genetic units, which are either dominated by debris flows or fluvial processes. Irrespective of the lithology in the catchment area, the overall stacking pattern shows increasing fluvial activity towards the top of the successions, by coeval reduced debris flows.

MIXED SILICICLASTIC/CARBONATE ENVIRONMENTS FROM THE CENOZOIC NORTH ALPINE FORELAND BASIN: POSSIBILITIES AND LIMITATIONS OF INTERPRETING COMPLEX EPI-CONTINENTAL SEDIMENTS (UPPER MARINE MOLASSE, EARLY MIOCENE)

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The Cenozoic, North Alpine Foreland Basin is characterized by large scale alternation of marine and non-marine conditions constituting the classic Molasse sedimentary sequence. This dramatic fluctuation of sedimentary regimes has been related to the complex interaction of tectonic uplift and erosion of the alpine chain to the south, the varied background geology of the stable European platform to the north, eustatic sea level changes and not the least, paleogeographic developments including the formation of the Paratethys Seaway.

The resulting marine sediments of the Upper Marine Molasse (OMM) are mostly dominated by siliciclastics, but also contain intriguing mixed siliciclastic/carbonate environments. Although carbonates are spatially and temporally isolated, the analysis of their biogenic constituents and facies relationships provides a wealth of paleoecological information in addition to the sedimentological data at hand.

This study is based on new detailed sedimentological and paleontological analysis of classic localities from the Lower Miocene, Upper Marine Molasse Zone from southwestern Germany. These localities include, among others, a mixed siliciclastic/carbonate environment with higher energy, cross-bedded sands and bryomol type carbonate sediments ("Randengrobkalk"), an isolated mass occurrence of turritellid gastropods ("Erminger Turritellenplatte") and tidal dominated sandwave deposits of various types ('Grobsandzug", "Baltringer Schichten" and "Heidenlöcher beds") indicating sub- to intertidal environments.

Paleontological data is juxtaposed to sedimentological criteria, and both are compared to large scale modelling of tidal and wave movement within the OMM sea, as well as to climatic reconstruction derived from both terrestrial and marine records from the Miocene of Europe. The possibilities and difficulties of applying actualistic sedimentary and facies models from recent epi-continental seas for interpretation is discussed, not the least with respect to the rapid changes in background tectonics setting, paleogeography, and climate which dictated sedimentation in the Molasse Sea during the Cenozoic.

CYCLICITY OF SHALLOW-MARINE, WARM-WATER CARBONATE PLATFORM DEPOSITS: FACIES ARCHITECTURE AND SEQUENCE STRATIGRAPHY OF THE LATE CARBONIFEROUS NY FRIESLAND PLATFORM (SPITSBERGEN)

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During the Late Carboniferous (late Moscovian to Kasimovian), a spacious, warm-water carbonate shelf, the Ny Friesland Platform, developed at around 25°-30° N along the northern margin of the supercontinent Pangaea. The fossiliferous platform strata are characterized by a pronounced cyclicity, consisting of stacked parasequences, which are separated by subtle discontinuity surfaces and show specific facies successions consisting of up to 4 facies sets:

Locally occurring *Transgressive Facies Sets* at the base of the parasequences consist of intraformational, coarser-grained resediments (peloidal, litho- to bioclastic rudstones) or nodular mudstones interbedding with thin, fine-laminated claystones to marls. While the coarser resediments comprise a considerable part of reworked material from the underlying strata, the fine-grained deposits accumulated in areas marked by sediment-starved conditions. Both types of transgressive facies formed under a general rising sea level after the initial flooding of the platform surface.

Mid-platform Facies Sets conformably overlie the transgressive sediments and consist of thick- to medium-bedded, fossiliferous wackestones dominated mainly by echinoderms, brachiopods, bryozoans and/or fusulinid foraminifers, locally embedding lateral restricted enrichments of horn-shaped, solitary, rugose corals. These sediments formed under quiet-water, open-marine, oxygenated conditions on submarine, muddy flats below the fair-weather wave base, when water depth was highest during maximum transgression.

Inner-platform Facies Sets consist of very thick- to medium-bedded dolomite and carbonate beds marked by the common occurrence of stylolites. The limestones comprise associations of various microfacies types, representing different shallow-submarine to peritidal platform environments. High-diverse, fossiliferous packstones to wackestones marked by changing component compositions of echinoderms, small foraminifers, coralline red algae, dasycladalean green algae, phylloid algae, chaetitides, colonial rugose and tabulate corals and *Palaeoaplysina*, represent open-water, sandy to muddy flats. Within these sediments, scattered and isolated, smaller calcareous algal and coral knobs and larger, partly amalgamated *Palaeoaplysina* mounds occur. The deposits grade into ooidal-, peloidal- and skeletal grainstones to packstones, reflecting wave-or tide-agitated nearshore areas and sandy shoals or bars, which protected semi-restricted, low-energy lagoons or tidal flats. The latter are represented by mudstones and peloidal, low-diverse, fossiliferous wackestones comprisong mainly echinoderms and mollusks.

Sabkha Facies Sets occur locally at the top of individual parasequences and consist of laterally discontinuous, thin horizons comprising *Microcodium* or caliche facies (mainly peloidal, litho- to bioclastic pack- to rudstones). These capping beds reflect a terrestrial, low-relief sabkha, which prevailed under arid to semi-arid climatic conditions during the emersion of the platform top. Within these areas, the emerged limestone strata were affected in varying degrees by iron-staining, desiccation, meteoric alteration, dolomitisation, erosion, reworking and pedogenesis within weakly developed palaeosols.

The stacked parasequences are interpreted as successive shallowing-upwards cycles, separated by subaerial exposure surfaces. They reflect glacio-eustatic, high-frequent and high-amplitude sea-level fluctuations due to volume changes of the ice caps of southern Gondwana Land.

According to biostratigraphic data, the parasequences represent 4th order cyclothems (duration of 200–400ky), which superimpose a 3rd order, late-highstand sea-level curve. The latter is reflected by an overall thinning-upwards trend of the individual parasequences and an internal shift of the proportions and composition of the different facies sets due to an overall shallowing-upwards trend and decreasing accommodation space of the depositional area.

COMBINING «NEW» AND TRADITIONAL CHRONOMETERS FOR THE CALIBRATION OF BASIN FORMATION AND PROCESSES RECORDED IN ANCIENT SEDIMENTS. EXAMPLES FROM THE PERMIAN AND TRIASSIC

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Over the past ten years the analytical procedures of radioisotope age dating have seen substantial improvements, which helped raising the resolution of dating magmatic rocks and volcanic ash layers in fortunate cases to the sub-m.y.-level. In suitable geological settings the highly precise and accurate new age data allow the in-situ calibration of basin formation and the quantification of sedimentary processes and evolutionary rates of organisms with no need to involve time-scales with their inherent uncertainties.

Rocks of Permian and Triassic age and with outstanding exposures and excellent "traditional" stratigraphic constraints in the Southern Alps and in China have played a key role in improving and testing the U-Pb-zircon chronometer applied to sedimentary systems. The geological problems addressed to date cover topics as different as (A) linking surface and deep crustal processes and (B) the evaluation of sedimentary rhythms and the quantification of carbonate accumulation.

(A) In an exceptional section across the South Alpine Lower Permian crust, high-resolution U-Pb zircon age data document a close temporal link between continental basin formation, shallow crustal magmatism and the emplacement of large volumes of mafic magmas in the lower crust (Ivrea Zone) possibly documenting the initial stage of a phase of continent-scale strike slip.

(B) The integration of high-resolution numeric ages with a tight bio- and lithostratigraphic framework for Middle Triassic platform carbonates and basin deposits in the Southern Alps not only indicate high rates of carbonate production and accumulation when observed at sufficiently small time intervals but also confirm the existence of sub-Milankovitch high-frequency stratal patterns in platform carbonates.

Coordinated inter-laboratory calibration experiments are now underway and promise further progress of the quality of radioisotope age dating and of the comparison of different chronometers. In future such tools are expected to become more widely applicable and they will likely play a crucial role in improving the quantified analysis of ancient sedimentary systems.

GEOLOGY OF THE BOSNIAN FLYSCH (SARAJEVO – ZENICA AREA, BOSNIA AND HERZEGOVINA) PART 1: AGE AND PROVENANCE

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The Bosnian Flysch is a Jurassic to Upper Cretaceous, 2-3 km thick carbonate-clastic tectonostratigraphic unit of the Dinaride thrust-nappe system. It is thrusted onto the Adriatic-Dinaride carbonate platform and itself is overthrusted by carbonate and ophiolite units of the Inner Dinarides. The Bosnian Flysch is made up of a lower, turbiditic to monotonous pelagic series composed of micritic limestones, marls, shales and siliciclastic-dominated sandstones (Vranduk Formation). The upper succession (Ugar Formation) is carbonate-dominated, comprising thin-bedded marly to micritic limestones and shales alternating with calcareous turbidites and debrites several tens of metres thick. There is a marked increase in the carbonate content in the Ugar Formation.

We present new biostratigraphic (foraminifera and calcareous nannoplankton), and sediment provenance data (whole rock geochemistry, heavy mineral chemistry, and detrital zircon fission track analysis) which are used to reconstruct sediment source rock lithology and provide new constraints on the age of sedimentation in the Bosnian Flysch basin.

A peculiar breccia horizon in the Vranduk Formation contains Urgon facies limestone clasts that are Barremian to Aptian in age. Calcareous nannofossils obtained from the pelitic intervals point to the same age, indicating erosion from a coeval carbonate platform into the basin. Nannofossils of the Ugar Formation mostly show Turonian to Maastrichtian ages but likewise contain Lower Cretaceous carbonate clasts.

X-ray fluorescence analyses of the trace elements Cr, Ni, V, Y, Zr and Sc provide evidence for the predominance of ultramafic and mafic rocks in the source area. Zr/Sc ratios best correspond to an active margin setting of the source crystalline units. This is confirmed by Cr/Ni and Zr/Sc ratios which reveal that sediment recycling has played no major role during the sedimentation and suggest that the trace element pattern is linked to source crystalline lithologies. Cr/V vs. Y/Ni shows that felsic crystalline units were also involved into source area erosion.

The heavy mineral spectra are dominated by Cr-spinel and also comprise much zircon, rutile, garnet, tourmaline, apatite, monazite and titanite whereas kyanite, zoisite, epidote are only locally significant. Chemical compositions of selected heavy mineral species determined by electron microprobe yield additional information on source lithology. Mostly all tourmaline crystals are derived from metapelitic sources. Metamorphic zoning points towards a low-grade Barrovian metamorphic source. Garnet geochemistry indicates a variety of source lithologies. Most dominant are Barrovian type metamorphic rocks and in samples where kyanite, zoisite and epidote are present, a garnet population derived from amphibolite to granulite facies metapelites appears. 60 to 80% of the rutile crystals are of metapelitic origin as deduced from their Cr/Nb ratio, the rest is derived from metamafic lithologies. Zr-in-rutile-thermometry reveals a broad distribution of calculated metamorphic temperatures between 450 to 1050°C but in many samples a clear peak is observed at 550 to 650°C temperatures.

Cr-spinel is the most abundant heavy mineral throughout the Bosnian Flysch. The high amounts of this mineral correspond to the predominance of ophiolite units of the adjacent ophiolite mélange belt. The data allow to discriminate between abundant mantle-derived spinels and a subordinate magmatic-derived population. Most mantle-derived spinels are of harzburgitic affinity. Magmatic Cr-spinels amount only to 2–24% in the entire spinel association.

Detrital zircon fission track data from a single sample from the Bosna river valley shows a wide age distribution (80 to 270 Ma) implying that the burial temperature was not sufficient for reset. The youngest age population lies at 121±21 Ma. This nearly syndepositional cooling may indicate either a relatively rapid exhumation of zircon-bearing felsic lithologies in the accretionary wedge or a contribution from Early Cretaceous volcanism as indicated by significant proportion of euhedral crystals.

Our results indicate a complex source rock assemblage comprising carbonates; low to medium grade, Barrovian type metamorphics that are mostly metapelitic but also metamafic; subordinate high-pressure metamorphics as well as ultramafics. This challenges existing models on the geodynamic evolution of the Bosnian Flysch.

BASIN ANALYSIS AND NUMERICAL MODELLING OF SOUTH ATLANTIC CONJUGATE PASSIVE CONTINENTAL MARGINS

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The main objective of this study is proposing a seismo-sequence stratigraphy model for the sedimentary successions deposited in key segments of the passive Brazilian and Uruguayan continental margins of the South Atlantic region.

Three seismic transects which are currently under investigation are located in the Campos, Santos and Pelotas basins with an approximate orientation N40W. They are between 340 and 320 km long.

Based on the available well data, logs and previous stratigraphic studies, as well as the resolution of the 2D seismic data, twelve key seismic reflectors along the three seismic profiles were chosen. The seismo-stratigraphic analysis of these profiles in the Campos and Santos Basin shows that the sedimentary succession, from the Neocomian until the Holocene, has a total thickness of around 1500 m below the current coastline and a maximum of 5000 m in the slope-basin area. In the Pelotas Basin, in the Uruguayan margin, a similar thickness of sediments is observed in the proximal region, but the slope-basin succession reaches approximately 8000–9000 m thickness. Regionally, the basement is formed by tholeitic basalts of Hauterivian – Barremian age, underlying the first continental sediments of Barremian age, which onlap the top of the basement towards the South American Craton. The top of the rift sequence is marked by a clear and continuous reflector along the profiles, which underlies the Aptian – Albian rocks. Both in the basement and the rift sequence the internal reflectors are not clear and anomaly zones are common, due to the high impedance of the overlying salt succession.

During a period of relative tectonic quiescence, along the initial ocean opening stage, the syn-rift Aptian-Albian salt sequence was deposited, which has varying thicknesses as a consequence of halokinetic structures, produced by subsequent sediment and water load. The thickness varies from 10 to 2000 m, but initially, during deposition, should have comprised between 1000 and 2000 m. In the Pelotas Basin, these salt deposits are absent, as well as diapirs and salt domes. Siliciclastic sediments deposited on shelf to slope environments compose most of the rocks deposited during this time. However, some authors report that an evaporitic succession is present, but restricted to the northern part of the Pelotas Basin. An indistinct reflector interrupted by diapiric anomaly zones marks the top of this syn-rift succession in the Santos and Campos basins. The salt movement occasionally associated with growth faults and rollovers structures, affects the complete sequence up to the Miocene rocks. It controls the late Cretaceous and Tertiary facies distribution and contributes to the trapping of the major hydrocarbon accumulations. Within these salt structures and commonly along the succession, the internal reflectors are hard to trace. In the Campos Basin, it is equally difficult to follow the other reflectors, because of the severe deformation and anomalous reflections.

In the post-rift phase distinct depositional conditions caused obvious differences in the stratigraphy of these three basins. From the Albian until the Turonian regional sea-level rise, thermal subsidence and an abundant sediment influx, higher in the Santos Basin, caused a regional transgressive pattern, with sediment thicknesses between 1000 and 2000 m. This interval is marked by a uniform horizontal retrogradational reflection pattern. From the Turonian until the Paleocene, in the Santos Basin the sediment input increased and a major shelf progradation occurred. About 1500 m of rocks with a horizontal progradational reflection pattern are observed along platform and slope, while the Campos Basin maintains transgressive conditions. Here, the sedimentary succession is thinner, and the regional retrogradational trend shows only intermittent episodes of shelf progradation with downlap. Contrastingly, in the Pelotas Basin, the continuous horizontal retrogradational and aggradational patterns are intercalated with some episodes of shelf progradation. This suggests relatively constant sea level, sediment input and continuous subsidence rates in comparison to the other two basins located northward. This trend was maintained until the Holocene, when a 4000 to 6000 m thick succession was deposited.

The Tertiary, from the late Paleocene onwards, is characterized in the Santos Basin by a widespread and continuous progradational succession, with marked turbiditic deposition in the lower-slope and basin areas, evidenced by a thickening of the sedimentary succession. In the Campos Basin, the increase in sediment input led to deposition of a relatively thick sequence on the shelf and top-slope (around 2500–3500 m) area. It thins progressively towards the basin (1500–2000 m), which is characterized by discontinuous reflectors interrupted by salt structures and turbiditic fans associated with submarine erosion surfaces.

Currently, the quantitative basin modeling is under elaboration and will provide rates of subsidence, crustal flexure, sea-level changes, geometry and deposition of these three basins through the time.

SEDIMENTOLOGY, HYDROGEOLOGY AND ENGINEERING GEOLOGICAL IMPLICATIONS OF HUGE CLAY-RICH LANDSLIDES IN MOUNTAIN SLOPES

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Mountain slopes in the Alps and in the Apennines are deeply scarred by huge landslides affecting weak flysch rock masses. Commonly this is due to complex deep seated roto-translational earth slides and earth flows that can reach considerable dimensions and involve up to about 50 Mil. cubic meters of clay-rich debris. In many cases, first failure dates back to the Lateglacial – Early Holocene. Nevertheless, landslide bodies were built up all through the Holocene, by way of a sequence of events bracketed by phases of dormancy lasting decades to centuries (long). The long-term multiphase emplacement of landslide deposits has sedimentological, hydrogeological and engineering geological implications that, after all, are worth being considered for palaeo-environmental reconstruction and hazard assessment. In fact, buried soils or woodlands mark ancient ground surfaces and allow dating of Lateglacial–Holocene slope instability that make it possible to speculate over long-term climate changes. At the same time, the shear-breccia horizons found at the interface between older and younger deposits of differentiated consolidation degrees, can be used as markers of internal weak zones and of multiple shear surfaces in case of reactivation events. Moreover, hydraulic conductivity contrasts between landslide masses and boundary bedrock control groundwater pattern and lead to differentiated hydro-mechanical triggering mechanisms in the various sectors of the landslides. Conclusion is that assessment and control of huge clay-rich landslides, including reliable numerical models of landslide evolution, can only be achieved after in-depth investigation and monitoring is carried out. This can rely on traditional methods and on all the range of innovative geophysical and engineering tools are making available to geoscientists that, however, will always be responsible to turn data into relevant information by keeping clear in mind the long term – large scale core issues of natural phenomena.

SPECTROSCOPIC INVESTIGATIONS AND PARTICLE ANALYSIS ON OCEAN SEDIMENTS METHODICAL DEVELOPMENT AT THIN SECTION OF THE CORE SO147/106KL (PERUVIAN CONTINENTAL SHELF, MIS 5E)

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Digital image processing of thin sections is used to produce high-resolution data. In this study two different image-processing methods are compared with each other and linked together, based on a marine sediment core of the drilling site SO147-106KL at the Peruvian shelf (Rein et al. 2006).

RADIUS is a particle analysis application, developed by Seelos & Sirocko (2005), which classifies particles in digital photographs of thin sections. The particle detection is based on colour detection, therefore the classification of the particles is depending on grain sizes. The second method COMPONENTS (Rein & Jäger, acc.) analyzes the sediment composition by applying band ratios on multispectral images of thin sections. For generating multispectral pictures for COMPONENTS, a photograph routine was developed during this study.

In order to compare both methods, a MATLAB® module PhaseAnalysis was programmed and incorporated to the RADIUS environment. This module evaluates the results of COMPONENTS and makes them available in RADIUS for a subsequent combined treatment. The linkage of particle analytics with multi-spectral phase analytics offers several advantages: The used band ratios are more accurate in the detection of particles as well as phases than absolute grey values. Thus, improvements of the particle analysis results as well as a mutual validation of the results of both methods are possible. On the basis of quartz and carbonate, a calibration curve was calculated. Through this the relative surface quota of image analysis can be converted into weight percentage, in order to compare the results with conventional analysing methods.

This routine is applied to a laminated sediment core from the Peruvian continental margin, representing the MIS 5e-d transition. Obviously the grain sizes of the clastic sediments change during the $\delta^{18}O$-increase. This documents a moderately increasing fluvial runoff on the continental shelf during times of changing sealevel and continental precipitation accordingly to the global signal. The amount of lithic supply is controlled by the discharge of river floods in northern and northern central Peru and the current inter-annual SST variability is linked to ENSO variability.

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SEDIMENTOLOGICAL, GEOCHEMICAL AND MICROPALEONTOLOGICAL INVESTIGATIONS OF LAKE SEDIMENTS TO RECONSTRUCT LATE GLACIAL/HOLOCENE LANDSCAPE EVOLUTION AT LAGO BUDI (CHILE)

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The coastal lagoon Lago Budi, located in southern Chile (38.9° S) can be characterized through elevated ranges of salinity (7– ~20 ppm), which arise from a spatial connection to the Pacific Ocean. Due to its location, Lago Budi serves as a sediment trap, indicating Holocene landscape evolution.

During a field campaign (German Research Founding Project "Late Glacial/Holocene Landscape Evolution at Lago Budi, Chile (38.9° S) - Paleoseismic Investigations on Lake Sediments") several piston cores were taken to obtain detailed information on intra-lagoon sedimentation processes. Furthermore, the compilation and dating of tsunamigenic sediments should allow a deeper understanding of seismic events and associated tsunami waves on a temporal and regional scale. The influence of such singular events on lake chemistry and the corresponding microfauna also has to be taken into account.

Thus, the aim of the current study was to develop a multi-proxy approch providing the possibility to reconstruct Late Glacial / Holocene landscape evolution with simultaneous consideration of ecosystem modifications mainly caused by the input of allochtonous tsunamigenic sediments.

Based on the analysis of one piston core with a total length of 6 meters a wide range of sedimentological, geochemical and microfaunistical methods was carried out in reconstructing marine, brackish and freshwater conditions, reflecting a weakening respectivly strengthening of the marine impact. To distinguish event-associated disturbances and long-term modifications of the ecosystem grain-size analysis were performed by using laser diffraction technology. In combination with measurements of the magnetic susceptibility several sandy layers could be detected, indicating the existence of tsunamigenic deposits within the lake. In addition, X-ray diffractometry measurements enabled us to determine the origin and structural composition of these layers.

The results of geochemical analysis primarily based on atomic absorption spectrometry and CNS were used to deviate a chronological sequence of different types of paleoenvironments in terms of salinity and nutrient content. Furthermore C_{org}/N-ratios were calculated to identify the influence of terrigenous input.

One of the main focuses of our study was the use of micropaleontological indicators. By applying a paleoecological approach, several taxa of foraminifera, ostracods and molluscs representing brackish respectivly marine environments were identified and analysed quantitatively to reconstruct past habitat characteristics.

SEISMIC SEQUENCE STRATIGRAPHY AND STRUCTURAL STYLES IN THE TARFAYA BASIN (MOROCCAN ATLANTIC MARGIN, LOWER CRETACEOUS TO PRESENT)

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2D marine seismic reflection data from the Tarfaya Atlantic margin of southern Morocco, interpreted in the light of well log data, allowed us to define a structural and stratigraphic framework of the Tarfaya basin from the Lower Cretaceous to the Present and to quantify the interplay between the developing structure, sedimentary systems and the resulting sequence stratigraphic architecture.

In the first step of this study, the stratigraphic framework of the area was established by the application of a general seismo- and tectonostratigraphic analysis. We defined 9 seismo-stratigraphic sequences based on a classification of seismic facies, reflector patterns and regional unconformities that allow to correlate the deposits of the Tarfaya shelf since the Precambrian:

1) The seismic basement is formed by Precambrian- Paleozoic (Pr-Pz) folded and metamorphic rocks that are bounded at the top by a major erosional Hercynian unconformity and is marked by hummocky seismic facies with high amplitude and low frequency reflectors. This sequence is affected by ENE-WSW trending faults.
2) On top of the Hercynian the Late Triassic - Early Jurassic mega-sequence was deposited (Tr-J1-1). It is already synrift and consists of terrigenous clastics and minor evaporite sediments and basaltic sills. It is bounded on top by the Jurassic breakup unconformity. The seismic facies is characterized by subparallel reflections, indicating uniform subsidence. This sequence is marked by half graben structures which are bounded by NE-SW striking, offshore dipping listric normal faults.
3) The formation of Puerto Cansado (Upper Jurassic (J2.1) is composed of oolithic and bioclastic limestones, laterally grading into marls or sandstones, indicating the installation of a well structured rimmed carbonate platform with associated lagoon. Its seismic image is characterized by subparallel reflections with high amplitude on the shelf and the upper slope and condensed reflectors on the lower continental slope and the rise
4) The formation of Tan Tan (Lower Cretaceous (Kr1)): marine-deltaic sandstones and shales. The sequence overlies unconformably the Jurassic sequence and is characterized by parallel to subparallel reflections with good continuity and high amplitude disrupted by an area of discontinuous lower amplitudes which indicate intervals of sands and shale. The succession is characterized by growth faults due to the Pyrenean orogenic events and gravity sliding.
5) The formation of Aguidir (Upper Albian – Lower Cenomanian (Kr2.1)) consists of transgressive deposits (marls and limestone). According to extrapolated well and seismic information, this sequence consists of lagoonal, tidal and shallow marine muds and sands. In seismic lines this sequence is characterized by parallel to subparallel reflections with varying amplitude.
6) The formation of Labtaina (Upper Cenomanian – Maastrichtian (K2.2 and Kr2.3) is composed of dark brownish and greyish laminated hemipelagic chalks, alternating with nodular limestones. The sequence is reduced in thickness and marked by parallel seismic facies with continuous and variable amplitude and constitutes of hemipelagic marls and carbonate.
7) The formation of Samlat (Paleogene (M01.1 and Mo1.2) is characterized by marine clastic sediments and siliceous chalks with chert concretions. The base of the unit is formed by the second major regional erosional unconformity, as a consequence of Alpine movements. The sequence is marked by low amplitude and subparallel to chaotic reflectors.
8) The formation of Tah (Neogene (M02.1)): shallow marine sandy claystones, calcarenites and sandstones. This formation is marked by transparent to parallel reflectors with low amplitude.
9) Plio-Quaternary (MO2.2): marked by an erosional truncation that separates the shallow marine sandy claystone of Miocene formation and the Plio-Quaternary Sandstone. In seismic lines this sequence lies unconformably over the older sequences, marked by a downlapping lowstand wedge and characterized by low amplitude reflectors and transparent to parallel seismic facies.

INTERACTIONS BETWEEN ENVIRONMENTAL CHANGE AND SHALLOW-WATER CARBONATE BUILD-UP ALONG THE NORTHERN TETHYAN MARGIN AND THEIR IMPACT ON THE EARLY CRETACEOUS PALEOCEANOGRAPHIC RECORD

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The evolution of the early Cretaceous, northern Tethyan carbonate platform was not only influenced by changes in sea level, detrital influx, and surface-water temperature, but also by changes in trophic levels. We distinguish between phases of carbonate production dominated by oligotrophic photozoan communities and by mesotrophic and eventually colder water heterozoan communities. Superimposed on this bimodal trend in platform evolution were phases of platform demise for which we provide improved age control based on ammonite biostratigraphy. The initial phase of these episodes of platform demise corresponds in time to episodes of oceanic anoxic events (OAEs) and environmental change in general. Based on a comparison between the temporal changes in an early Cretaceous, ammonite-calibrated, $\delta^{13}C$ record from southeastern France and coeval changes in the platform record, we suggest that the history of carbon fractionation along the northern Tethyan margin was not only influenced by changes in the oceanic carbon cycle such as in the rate of production and preservation of organic and carbonate carbon, and in the size of the oceanic dissolved inorganic carbon (DIC) reservoir, but also by the above-mentioned changes in the ecology and geometry of the adjacent carbonate platform. Phases of photozoan carbonate production induced positive trends in the hemipelagic carbonate $\delta^{13}C$ record. Phases of heterozoan carbonate production pushed the $\delta^{13}C$ system towards more negative values. Platform drowning episodes implied an initial increase in $\delta^{13}C$ values, followed by longer-term decrease in $\delta^{13}C$ values.

TECTONO-GEOMORPHIC CONTEXT OF GEODETIC DATA ACROSS AN ACTIVE BASIN AND RANGE NORMAL FAULT, CRESCENT VALLEY, NEVADA

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Geodetic strain and late Quaternary faulting in the Basin and Range province is distributed over a region much wider than historic seismicity, which is localized near the margins of the province. In the relatively aseismic interior, both the magnitude and direction of geodetic strain may be inconsistent with the Holocene faulting record. We document the best example of such a disagreement across the NE-striking, ~55° NW-dipping Crescent normal fault, where a NW-oriented, 70 km geodetic baseline records contemporary shortening of ~2 mm/yr orthogonal to the fault trace. In contrast, our morphometric, paleoseismic, and geochronologic analyses of the Crescent fault imply that an extensional surface-rupturing earthquake occurred during the late Holocene. An excavation across the fault at Fourmile Canyon reveals the most recent event occurred at 2.8 ± 0.1 ka, with net vertical tectonic displacement of 4.6 ± 0.4 m, corresponding to the release of ~ 3 m of accumulated NW-SE extension. Measured alluvial scarp profiles suggest a minimum rupture length of 30 km along the range front for the event, implying a moment magnitude Mw between 6.6 and 7.3. No prior event occurred between ~2.8 ka and ~6.4 ± 0.1 ka, the ^{14}C calender age near the base of the exposed section in the excavation. Assuming typical slip rates for Basin and Range faults (~0.3 mm/yr), these results imply that up to 1/3, or ~1 m, of the extensional strain could have reaccumulated across the fault. However, the contemporary shortening implies that the fault is unloading due to a transient process, whose duration is limited to between 6 years (geodetic recording time) and 2.8 ka (the age of the most recent event). These results emphasize the importance of providing accurate geologic data on the time scale of the earthquake cycle in order to evaluate geodetic measurements.

USE OF CATHODOLUMINESCENCE ANALYTICS ILLUSTRATED BY THE STABLE MINERAL GROUP MONAZITE-XENOTIME-ZIRCON FROM TRIASSIC SANDSTONES OF NE-BAVARIA

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Monazite, xenotime, and zircon in heavy mineral separates of siliciclastic sediments show similar optical properties but can easily be distinguished by means of cathodoluminescence (CL).

Within this stable group **zircon** is the most common mineral with three known luminescence colours: yellow, blue and violet (marshall, 1988). Besides, a white or a grey luminescence colour can occur very frequently. The white and grey luminescence colours are however only high and low intensity variations of the yellow and blue grains, respectively. In the CL-spectra of the examined zircons REE^{3+} primarily appear as activators. Four Dy^{3+}-narrow bands at 484 nm, 576 nm, 665 nm, and 757 nm are very characteristic, through which the first two are most strongly developed. Typical are smaller narrow bands at 480 nm, 545 nm, and 615 nm, which point out to an Eu^{2+}-Ion, Tb^{3+}-Ion and Eu^{3+}-Ion, respectively. Sm^{3+} forms three smaller narrow bands at 597 nm, 643 nm, and 703 nm. Blue luminescent zircons are characterized by a clearly developed band within the range of short-wave radiation. Within the spectra of yellow luminescent zircons the band in the short-wave region is usually missing. Additionally, another broad band occurs at 560 nm. Violet luminescent zircons show an increased intensity between 400 nm and 500 nm. Furthermore, Sm^{3+} is enriched compared with the otherwise dominating Dy^{3+}.

Xenotime shows a bottle-green CL-colour. Likewise to zircon, the emission bands of Dy^{3+} (484 nm, 576 nm, 665 nm, and 757 nm) dominate the CL-spectra of xenotime beside those of Tb^{3+} (480 nm and 545 nm) and Sm^{3+} (565 nm, 597 nm, 643 nm, and 703 nm). CL-spectra of xenotime are very similar to those of the blue zircons. The difference in colour can be explained by different intensities of the emission lines, which are strongly influenced by the crystal field and by the occurrence of intrinsic broad bands in zircons (Richter et al., 2006). These intrinsic bands between 400 nm and 500 nm are missing in the xenotime spectra.

Monazite appears to be non-luminescent, but shows a dull, very dark green colour. CL-spectra of monazite (Richter et al., in prep.) are very similar to those of the yellow zircons. Likewise to xenotime the intrinsic bands between 400 nm and 500 nm are missing. In addition, the characteristic band of Nd^{3+} appears between 850 nm and 920 nm. The Nd^{3+}-content in zircon and xenotime is commonly too low to be detected by CL-spectroscopy.

First quantitative investigations on heavy mineral separates of sandstones from the Middle Keuper and from the Lower Bunter of NE-Bavaria are carried out with the relatively simple CL-differentiation between monazite, xenotime, and zircon.

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MN^{2+}- AND REE^{3+}-ACTIVATED LUMINESCENCE OF SEDIMENTARY ARAGONITE: A GEOCHEMICAL AND EXPERIMENTAL APPROACH

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Aragonite is a very common mineral especially in Mg-rich marine and terrestrial sedimentary systems and in biogens, although calcite is the stable $CaCO_3$-modification at the earth's surface. Aragonite commonly has a complex trace element composition with numerous cations being incorporated on the Ca^{2+}-site in the crystal lattice. Anorganic crystals of different meteoric, marine, and evaporitic origin as well as biogen skeletons have been investigated in this study by trace element analysis (proton microprobe) and cathodoluminescence spectroscopy (HRS-CL) and compared to synthetic aragonite doped with Mn^{2+} and REE^{3+}.

Pure aragonite show dark greenish blue luminescence colours which originate from intrinsic emission bands at 440 nm and 540 nm. Detailed information on the point defects which are responsible for this luminescence have been lacking up to now. Mn^{2+} has been found to be the most important activator element in the freshwater biogens and in meteoric aragonite which contain up to 600 ppm Mn. Mn^{2+}-activation results in a greenish yellow luminescence commonly observed in aragonite (Sommer, 1972). In contrast, no Mn was detected by proton microprobe analyses in the marine biogens and the luminescence is generally weak. The broad emission band centred at 575 nm to 580 nm which is commonly detected in the CL-spectra can be attributed to the $^4T_{1g} \rightarrow {}^6A_{1g}$-transition in a Mn^{2+}-centre. The maximum emission is shifted towards lower wavelength compared to the corresponding band in calcite due to different kation-oxygen-distances in the crystal lattice. The luminescence intensity shows a linear correlation with the Mn-content in synthetic aragonite doped with 400 to 2000 ppm Mn and in natural samples containing <10 to 600 ppm Mn. Above 2000 ppm Mn, selfquenching effects depress the luminescence intensity. Similar to the CL of trigonal carbonate (Richter et al., 2003), Fe^{2+} seems to be the most important quencher in aragonite causing a depression of the luminescence, if more than approx. 2500 ppm Fe^{2+} are present. Other trace elements like Sr^{2+} do not affect the CL-intensity.

Rare earth elements, which are common trace elements in hydrothermal aragonite and might also be important CL-activators (Mariano, 1989), have only be found in evaporitic aragonite form the *locus typicus* (Aragonia/Spain). Yellowish orange to greenish colours were found depending on the predominant activated element. Sm^{3+}-activation result in orange colours, while Dy^{3+} generally shows greenish luminescence. Changes in the REE-pattern may result in zonation which is mapped by the luminescence. In the CL-spectra, narrow bands of Dy^{3+} at 480 nm, 575 nm, 660 nm and 760 nm and of Sm^{3+} at 560 nm, 605 nm, 645 nm and 705 nm are the dominating peaks. Emission lines of Tb^{3+} at 490 nm and 550 nm, Eu^{3+} at 615nm and Pr^{3+} at 600 nm may occur subordinately. Quantification of the REE^{3+} form the CL-spectra is difficult, because energy transfer between different ions and elements is very effective.

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TIMING OF MICROBIAL ENCRUSTATION ON CORALS DURING THE LAST DEGLACIAL SEA-LEVEL RISE, IODP EXPEDITION # 310 OFF TAHITI

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The rapid sea-level rise accompanying the last deglaciation is recorded by coral reefs characterized by extraordinarily voluminous microbial crusts (up to 80%) on the slopes of Tahiti. For reconstructing the exact course of deglacial sea-level rise and sea-surface temperature, the taxonomy of corals and geochemical tracers in their skeletons are currently studied by Science Party members of the IODP Expedition # 310. However, for reliable reconstructions, these parameters have to be distinguished from others including water energy, nutrient levels, light intensity, wave-base levels, and erosion of the hinterland. To gain this broader information, components other than corals need to be studied. In this respect, the microbialites are a potential archive for a wide range of environmental parameters but their paleoenvironmental significance is not sufficiently understood so far. Hence, our study aims at adding to the calibration of microbialites in order to unravel their environmental record.

Corals encrusted by coralline algae followed by microbial crusts, the so called microbialites, represent the typical repetitive sequence of the Tahitian deglacial reef-succession. The microbialites show two main growth patterns: an initial laminated structure and a successive dendritic to thrombolitic habit. Microbioerosion patterns in the microbialites and the underlying corals yield a record of environmental parameters – specifically with respect to relative light availability and palaeobathymetry – prior and during encrustation. Traces found in microbialites, coralline algal crusts and in the corals have been produced by phototrophic (e.g. cyanobacteria, chlorophytes, rhodophytes) as well as heterotrophic (e.g. bacteria, fungi, sponges, polychaetes) boring organisms whereby the quantity of microbioerosion in the coral skeletons is noticeable higher than in the coralline algal and microbial crusts. Preliminary results show that key-ichnotaxa for the shallow euphotic zone are very scarce or absent whereas most boring traces encountered are more typical representatives of fossil and recent deep-euphotic to even dysphotic (<1% surface illumination) environments. Traces of heterotrophic boring fungi and bacteria which are usually characteristic of the aphotic zone were frequently encountered. However, this seemingly “aphotic ichnocoenosis” has been detected mainly in the abundant cavities created by boring sponges or inside the coral porosity, reflecting the possibility for the local development of such an ichnocoenosis also in shaded niches of photic environments.

The information extracted from structural analyses as well as microbioerosion patterns will help to resolve the relative timing of the growth of oligotrophic zooxanthellate corals and the initial incrustation by the microbialites that tend to flourish in eutrophic conditions.

COMPONENTS – MULTISPECTRAL IMAGE ANALYSIS OF VARVED SEDIMENTS IN THIN SECTIONS

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COMPONENTS is a new method to automatically quantify sedimentary components in thin sections. It is based on a 6-band (multi-spectral) image analysis. First, the thin sections are scanned twice, under polarized and under unpolarized plain light. Then, the two images are stacked to a single multispectral image file, with the first three bands (blue = 1, green = 2, red = 3) resulting from the unpolarized light, and the bands 4 to 6 (blue = 4, green = 5, red = 6) from the polarized light run.

The next step is the discrimination of the major sediment components by their transmission spectra characteristics. We use an approach based on band ratios, also known as indices. By using band ratios, the reflection measured in different bands is normalized against each other and minor illumination variations (e.g. by sample thickness variations) are eliminated. By combining specific ratios we are able to detect all seven major components in the investigated sediments (pyrite, resin, carbonates, quartz, clay, diatoms and plant remains).

The automatic classification and the analogous classification show high concordances, but some systematic errors could be identified. Consequently, the next step is the correction of these systematic errors. Exemplarily, the transition zone between resin and sediment is falsely classified as clay (or fine clastic material) which is the result of the preparation process. During the correction process we identify all clay next to resin using neighbourhood matrices. Then, the fine clastic fringe is reclassified as resin. The description of other reclassifications would exceed the limit of this abstract.

After classification each pixel is attributed to one of the components. To identify seasonal layers or varves we need information on the occurrence and abundance of components in the sub-layers. Thus, we use a filter kernel (low pass filter) based on neighbourhood analysis to integrate the classification data within small horizontal units. Each pixel of the filtered maps now carries the information about the absolute or relative frequency of this component in a defined neighbourhood.

Finally, component occurrences along profile lines can be visualized as diagrams both within the image processing software and as an exported ASCII file to be displayed in common spreadsheet software. The work of the next months is the enhancement of the neighbourhood analysis and the frequency analysis of the components.

In the future, we will develop this method for automatic detection, classification and measurement of varves.

Bert Rein & Knut Jäger (accepted): COMPONENTS – Multispectral digital image analysis of thin sections. – Sedimentology.

LOWER PERMIAN (WOLFCAMPIAN) ABO RED BEDS OF CENTRAL NEW MEXICO (USA) AND THEIR RELATIONSHIP TO THE ANCESTRAL ROCKY MOUNTAIN OROGENY

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The Lower Permian (Wolfcampian) of central New Mexico is represented by red beds of the Abo Formation, which, at the type locality in the southern Manzano Mountains is about 300 m thick. Sedimentation occurred under mainly arid climatic conditions, sediment transport direction was mainly towards the south (Orogrande Basin).

Towards the N (Chama Basin), the Abo Formation interfingers with red beds of the Cutler Group, towards the S (Orogrande Basin) with shallow marine limestones of the Hueco Group. The Abo Formation is divided into the lower Scholle Member, overlain by the Cañon de Espinoso Member. In the Jemez region the lower member is dominated by shale with thin intercalations of sandstone and conglomerate, and two caliche horizons. The upper member is dominated by sandstone and conglomerate with minor shale intercalations.

The thin sandstone and conglomerate intercalations in the lower member occur as single beds or display stacking patterns and are interpreted as minor channel fills and sheetflood deposits on overbank floodplains. The thicker sandstone and conglomerate sheets of considerable lateral extent in the upper member are mainly composed of stacked channels separated by erosional surfaces of different order. These sheet sandstone and conglomerate facies (architectural element CH-channel) are interpreted to represent broad shallow channel fill complexes of a braided stream system.

Towards the S, grain size within the Abo Formation decreases. At the type section and in the Joyita Hills the lower member consists of thick shale intervals with thin intercalated conglomerate and sandstone beds (architectural element CH). In the upper part coarse-grained siltstone and fine-grained sandstone units commonly displaying different types of ripple lamination are intercalated, representing the architectural elements SB (sandy bedforms) and subordinate LS (laminated sand). These thicker siltstone-sandstone units form sheet bodies that are exposed as prominent ledges extending laterally over hundreds of meters. These silt- and sandsheet bodies were deposited in broad, shallow channels of a braided stream system during periods of high influx of silt and fine sand. Random fluctuations in flow velocity and deposition rate caused compound crossbedding. Coarse sandstone and conglomerate consist of reworked intraclasts (caliche and siltstone clasts); sand- or pebble-sized extraclasts such as quartz, feldspar and rock fragments are absent. This may indicate intrabasinal tectonic movements causing reworking of intrabasinal sediments.

In southern New Mexico (Robledo Mountains, Doña Ana Mountains and the southern San Andres Mountains) the Abo Formation interfingers with the platform carbonates of the Hueco Group. Abo red beds thus occur as "tongues" within the Hueco Group.

Unlike the nonmarine Abo red beds, the underlying Bursum Formation contains beds of marine limestone and calcareous shale. Thus, the Bursum is transitional between dominantly shallow marine carbonate facies of the Pennsylvanian and the continental red bed facies of the Lower Permian.

Regional synsedimentary tectonic movements of the Ancestral Rocky Mountain orogeny strongly influenced Bursum and Abo sedimentation, resulting in conspicuous lateral variations in lithofacies and thickness. The onset of Abo red bed sedimentation marks a significant tectonic pulse of the Ancestral Rocky Mountain orogeny. Precambrian basement uplifts were rejuvenated and acted as source of siliciclastic sediment that was transported mainly towards the south into the Orogrande basin, subordinately into the Paradox Basin towards the NW and into the Taos trough in NE New Mexico. During Abo sedimentation, tectonic activity ceased and the uplifts were almost completely truncated by upper Abo red beds.

FACIES OF THE HORQILLA FORMATION ACROSS THE PENNSYLVANIAN-PERMIAN BOUNDARY AT NEW WELL PEAK (BIG HATCHET MOUNTAINS, SW NEW MEXICO, USA)

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At New Well Peak (NWP) in the Big Hatchet Mountains, southwestern New Mexico (USA), the Pennsylvanian-Lower Permian (Wolfcampian) section is composed of an exceptionally thick, well-exposed succession of shallow marine carbonate limestone termed Horquilla Formation. At NWP, the Horquilla Formation is ~ 1 km thick, dips 20-30° to the SW, rests with erosional disconformity on the Mississippian Paradise Formation and has its top faulted out. Nearby outcrops indicate that the Lower Permian Earp Formation rests disconformably on the Horquilla Formation. The NWP section of the Horquilla Formation can be divided into three lithologically distinct intervals: (1) lower member of sandy limestones, calcarenites and oolitic limestones, ~ 200 m thick; (2) middle member of cherty, thick-bedded limestones, many with silicified *Chaetetes*, ~ 300 m thick; (3) and upper member of thin-bedded limestones with especially rich fusulinacean assemblages, ~ 500 m thick.

The upper member crosses the Pennsylvanian/Permian boundary. At NWP, the uppermost 250 m of the Horquilla Formation (sections A and B) consist of decimetre (mostly 0.3–0.8 m) bedded, gray to dark gray limestone, mostly micritic and fossiliferous. Silicified fossils occur in a few units. Abundant fossils observed on outcrop are crinoids, fusulinids and calcareous algae. Rarely, massive to indistinctly bedded limestone (3.3–4.5 m thick) and cherty limestone occur.

Limestones are dominated by muddy textures with bioclastic wackestone being by far the most abundant microfacies. Grainstone is rare, and more abundant within the uppermost 70 m. Limestones are characterized by a diverse fossil assemblage indicating a shallow, subtidal low-energy open marine setting with normal salinity. High-energy conditions indicated by grainstone were rarely developed. No transgressive or regressive trends are observed within most of the depositional sequences. Within the uppermost part a regressive (shoaling upward) trend is observed in some sequences (wackestone grading upwards into grainstone).

Limestones are interrupted by several covered intervals, which most probably represent reddish marly shale horizons 0.0– 3.7 m thick. These covered intervals allow a subdivision of the succession into about 30 depositional sequences.

At the base of covered intervals root structures have been observed on top of many limestone units. On top of one unit a paleocaliche is developed. These root structures and the paleocaliche indicate that the limestones were periodically subaerially exposed and that the covered intervals represent phases of low sea-level.

The Horquilla Formation was deposited in the Pedregosa basin, which extends from SW New Mexico to SE Arizona and into northern Mexico and which was separated from the Orogrande basin to the east by the Florida high.

In contrast to the Orogrande basin, where sedimentation was strongly influenced by syndepositional tectonics, carbonate sedimentation in the Pedregosa basin seems to have been mainly influenced by glacioeustatic sea-level fluctuations. Thus, carbonate sedimentation was periodically interrupted by sea-level drops causing subaerial exposure and deposition of reddish marly shale. Siliciclastic influx as observed in correlative successions of the Orogrande basin is completely lacking.

THE THERMAL AND MATURATION HISTORY OF TERTIARY ARCTIC BASINS – A 3D INSIGHT INTO THE MACKENZIE BASIN, CANADA

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Due to Plio-Pleistocene surface cooling and deep permafrost formation, Arctic basins in many cases have exceptional temperature histories. Understanding this is not only vital for conventional hydrocarbon exploration but also for studies on sub-permafrost gas hydrates. In most cases basin history is further complicated by tectonic uplift and erosion. A good example of this is the Mackenzie Basin, situated in northwestern Arctic Canada.

Due to extensive hydrocarbon exploration in the area for more than 40 years, a huge amount of subsurface data is available. This allowed us to reconstruct the stratal architecture of the exceptionally thick (up to 10 km) succession of Tertiary sediments. The succession consists of 8 stacked deltaic units (Fish River, Aklak, Taglu, Richards, Kugmallit, Akpak, Mackenzie Bay and Iperk Formations) that formed in response to hinterland uplift and sea level change. The Mackenzie Basin is characterized by complex and changing stress fields. This is due to its position in the transition zone between a compressive setting in the west (Beaufort Foldbelt) and an extensional passive margin setting in the east (Eskimo Lakes Fault Zone). In addition, the area was influenced by pulses of uplift in the Brooks Range to the southwest. Four main events of uplift and erosion in the Mid and Late Eocene, Late Oligocene and Late Miocene considerably affected the thermal history of the basin. The Late Miocene event resulted in a basin scale unconformity, the sub-Iperk unconformity.

The present contribution seeks to unravel the influences using 3D basin modelling. The model is calibrated by well temperature and vitrinite reflectance data down to the maximum depth of drilling of 4-5 km and allows us to reconstruct the thermal history beyond this depth. Model predictions and well temperature data indicate low present day gradients of 2 to 2,2°C/100 m. Vitrinite reflectance data indicate low maturities (<0,5% Ro) of sediments at depths shallower than 2500 m in the onshore area and shallower than 3000–4000 m offshore and thus also low temperature gradients during the past. Maturity increases to the southwest of the basin where uplift of Eocene sediments of more than 2000 m occurred. Low maturity thus is not only a consequence of low temperature gradients but also of uplift which, in the case of the Late Miocene event inhibited further maturation in the largest part of the basin since due to fast loading with Pliocene sediments, surface cooling and permafrost formation the process of re-equilibration was retarded. This may be a common feature in many arctic basins and has to be considered if hydrocarbon generation potential and composition of sediments are studied.

THE IMPACT OF AFFORESTATION ON TOTAL SUSPENDED SOLID CONCENTRATIONS IN SURFACE WATER AND RELATIONSHIP TO MAJOR IONS, ESPECIALLY TO PHOSPHORUS

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Introduction

Forestry activities can interact both positively and negatively with aquatic resources. Careful planning and management will mitigate against potential negative impacts (Anon, 2000). Afforestation and harvesting can lead to changes in the hydrology, sediment load and chemistry of streams. These changes may affect water resource management costs, stream biota and the health of fisheries. Some of the changes can be related to specific phases of the forest management cycle - mainly site preparation, thinning and felling (Hornung, Newson, 1986). Water quality parameters potentially affected by a clear-cutting include: the concentrations of total suspended solids (TSS) phosphorus and so on.

The main goal of this work was to demonstrate how the establishment of forestry on former agricultural land influences streamwater quality, specifically TSS concentrations and other related constituents.

Material and Methods

The study site located near Crossmolina, Co Mayo was previously used for agricultural purposes and was regularly fertilized up to 3 years before afforestation. The site preparation (mounding) took place in the spring 2003 prior to planting with Scots pine and oak. Monitoring of analysed variables was conducted for approximately a year both before and after forest establishment. Water samples were collected using passive stream samplers (PSS) in 4 sites that were likely under different environmental stress. A composite water sample was collected continually over the week of monitoring. From September 2002, an autosampler was installed on the bank of the stream outlet from the site. In water, the content of TSS was expressed in $mg.L^{-1}$ of the sample dry matter and element concentrations were determined by the ICP method. In soil, TSS contents were determined using the Laser Analyser Economy 20, firm Fritsch and total element concentrations by the AAS method.

Results

Concentrations of TSS in surface water in the main outlet and at the study sites PSS1, PSS2, PSS3 and PSS4 in Crossmolina fluctuated over the monitoring period depending on local weather conditions. Despite the high TSS concentrations (> 50 $mg.L^{-1}$) recorded in the last quarter of 2002 in PSS1–PSS4, concentrations in the main outlet remained low (2 to 4 $mg.L^{-1}$), well below the threshold of 50 mg/L (Anon, 2001). Mean TSS concentrations for the whole period were lowest in the main outlet, highest at PSS4. Site preparation, in March 2003, produced no sustained increase in TSS concentrations. While the contents determined in the main outlet of the study area had a slightly upward trend, the levels of TSS, at PSS4 showed an opposite declining trend. The decline in TP concentrations at PSS4 was significantly correlated with TSS at that sampling point [1].

$$TP = 92.9077 + 4.48905 * TSS;\ R = 0.599;\ p < 0.0002;\ (\mu g.L^{-1};\ mg.L^{-1})\ [1]$$

The correlations between available forms of Ca, Mg and K in the soil (Morgan's extractable concentration) and the content of clay and pH were investigated, some significant correlations were found.

Conclusion

- At the Crossmolina study site, no adverse impact of forest operations on surface water quality was detected. TSS contents in surface water were actually lower after afforestation than before;
- Total phosphorus in surface water in surface water correlated with TSS levels.

Acknowledgements

This work was supported by the Environmental Protection Agency and COFORD.

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NANNOPLANKTON CONSTRAINTS ON THE MIOCENE AGE OF OUTER DINARIDE FLYSCH SEDIMENTATION

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Tertiary siliciclastic flysch deposits are associated with the Outer Dinaride nappe front. They overlie Eocene platform carbonate to bathyal marl successions that in turn cover Cretaceous platform carbonates of Apulia and the Dinaride nappes. Planktonic foraminifer biostratigraphy indicates an Eocene age of flysch sedimentation, while a part of the southeastern occurrences have recently been dated as of Neogene: biostratigraphic data by de Capoa et al. (1995) indicate that in Central Dalmatia and to the SE, the flysch formation lasted up to the Early Tortonian. Remnants of Upper Cretaceous to Lower Palaeogene flysch are found in the inner part of the Dinarides (Bosnian and Durmitor Flysch, smaller patches of Cretaceous deep-marine clastic strata near Zagreb and Bosanski Novi).

We present new calcareous nannoplankton data from several localities in the entire Adriatic flysch zone. Areas of the regional sampling include the Trieste-Koper and Pazin Basins in Istrian Peninsula, Pag Island, Šopot section near Benkovac, Split area, and Montenegro. The youngest nannofossil assemblages correspond to the NN4-6 Zones, placing most of the flysch into the Lower-to-Mid-Miocene, most probably Langhian. In addition, much reworked species are commonly found from the Upper Cretaceous, and from the Middle and Upper Eocene – many of them have non-overlapping stratigraphic ranges. The obtained Miocene ages of deposition are rather uniform throughout the flysch zone.

Our new biostratigraphic results allow us to conclude that:

1. The reworked Upper Cretaceous and Lower Palaeogene nannoflora suggests that the Cretaceous platform carbonate nappes of the Outer Dinarides were extensively covered by marine sediments behind the present-day thrust front already since the Late Cretaceous.
2. The present-day position of the flysch basin is a result of migration of the orogenic deformation front in the Tertiary. During permanent convergence, the Cretaceous depozone has continuously migrated towards the Apulian foreland. The mass of clastic sediments (originated partly outside the Dinarides, as shown by a significant amount of detrital garnets derived from higher-grade metabasic source rocks that mismatch present-day Dinaride lithologies) has been cannibalized by submarine erosion and repetitively re-deposited in the migrating basin.
3. Basin migration progressed as a series of SE-NW elongated wedge-top basins.
4. By the Mid-Miocene, erosion of older flysch from top of the advancing Cretaceous carbonate thrust wedge was completed, and the flysch depozone switched to the Apulian foredeep. This is supported by coarse "molasse" sediments that prograde onto the Miocene flysch: they are dominated by carbonate clasts, and their pebble spectra retain the inverted stratigraphy of the Cretaceous carbonate platform covered by thin foraminiferal limestones and flysch.
5. On Apulia, and locally on the outermost nappes, there should be a widespread regional unconformity between the Eocene and the Lower-to-Mid-Miocene which has hitherto received only little attention.

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RELATIONSHIP BETWEEN SEDIMENTATION AND COEVAL THRUSTING: CRETACEOUS SYNOROGENIC SEDIMENTS OF THE NORTHERN CALCAREOUS ALPS (NCA), AUSTRIA

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The switch from passive margin to synorogenic sedimentation in the western NCA took place under deep water conditions and is documented by the transition from marly or siliceous carbonates to marls, sandy marls and coarse clastic deposits. Synorogenic sedimentation develops gradually and conformably from passive margin sedimentation in the Cenomanrandschuppe (CRS), the Allgäu and southern Lechtal thrust sheets. In contrast, synorogenic sediments on the northern Lechtal and the Inntal thrust sheets record surface uplift and subsequent erosion, then transgression and subsidence. To interpret these contrasting histories of synorogenic sedimentation correctly, I first discuss the expected distribution of synorogenic sediments in relation to nappe thrusting.

Cretaceous thrusts in the NCA were emergent and placed thrust sheets on top of deep water synorogenic deposits. Therefore a ramp-flat model is appropriate. Thrusting in a deep marine environment has following consequences: As the frontal part of the thrust unit climbs up the ramp, water depth above the area of structural thickening decreases. An isolated carbonate platform develops on top of the evolving structure, or, if vertical growth is fast, shortlived carbonate buildups, which shed biogenic detritus into the surrounding deep marine areas. Continued growth will uplift the thrust unit above the ramp and upper footwall flat above sea level. The thrust unit covers successively larger areas of the upper footwall flat and ends sedimentation in the overthrust areas.

The synorogenic sedimentary successions of the western NCA can be compared to specific positions in such a model (Ortner, 2003):

Upper Footwall sedimentation: On the upper footwall flat below the thrusted units, conformable onset of synorogenic sedimentation records distant onset of contraction related to orogeny, and deposition of shallow water biogenic detritus shows the approaching of the thrust unit. The youngest sediments below the thrust record the minimum age of thrusting at the point of observation. This situation is comparable to Aptian-Albian synorogenic sedimentation of the Tannheim and Losenstein Fms. on top of the Allgäu thrust sheet, which are overlain by the Lechtal thrust sheet, and to Albian-Cenomanian synorogenic sedimentation of the Lech Fm. on top of the southern Lechtal thrust sheet, which is overlain by the Inntal thrust sheet. The uppermost Lech Fm. locally contains shallow water detritus ("Urgonian") transported by gravity flows and thereby records the destruction of carbonate buildups at the flanks of the approaching Inntal thrust sheet.

Thrust-sheet-top sedimentation: On top of the thrust unit, where structural thickening has taken place, unconformable transgression of terrestric sediments on deeply eroded older rocks records surface uplift. Growth geometries in thrust-sheet-top deposits record internal shortening of the thrust sheet after emplacement. The Branderfleck Fm. on top of the northern Lechtal thrust sheet and of the Gosau Group on top of the Inntal thrust sheet are found in this structural position.

In the foreland and the hinterland of the structure, undisturbed synorogenic sedimentation will continue. The CRS formed the northern continuation of the Allgäu thrust sheet prior to the Campanian, when it was overthrust by the Lechtal thrust sheet. The CRS has a conformable and continuous synorogenic sedimentary succession from the Aptian to the Campanian, overlapping both Upper Footwall sedimentation below and thrust-sheet-top sedimentation on top of the Lechtal thrust sheet. The CRS formed the foreland during thrusting of the northern Lechtal thrust sheet. The hinterland in relation to the northern Lechtal thrust sheet record conformable sedimentation up the Cenomanian, and was then overthrust by the Inntal thrust sheet. It forms the upper footwall in relation to thrusting of the Inntal thrust sheet.

Using such a model for synorogenic sedimentation and coeval thrusting has great predictive power, especially when working in poorly exposed areas, because it uses simple geometric relationships between syntectonic sediments and their substratum.

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CARBON AND OXYGEN ISOTOPES AS INDICATORS OF POLYGENIC NATURE OF THE MIDDLE MIOCENE (BADENIA) RATYN LIMESTONE IN WEST UKRAINE

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Evaporite replacements and their associated fabrics within carbonate strata are documented in many studies. The timing and conditions under which the complex processes of the dissolution and replacement occurred, can be established when integrated standard petrographical techniques and stable isotopic analyses are used. We used such an approach to the Middle Miocene limestones which are physically and (partly) genetically related to Badenian gypsum deposits and which are called "Ratyn Limestones". The term itself was coined for marine, massive limestones which are overlying gypsum deposits in Podolia; when gypsum is lacking, the Ratyn Limestones occur above sandy and Lithothamnium limestones. The earlier study of the stratotype section in the Mount Ratyn near Lviv showed that only the uppermost (10-cm-thick) part of the limestones contains a marine fauna, and that most limestones are barren, with textural indications of the former presence of gypsum. In the Anadoly section near Khotyn, in addition to the two limestone types recorded in the Mount Ratyn, also limestones which originated during the gypsum deposition stage owing to inflow of new seawater. All these limestones differ in respect to their textures and their $\delta^{13}C$ and $\delta^{18}O$ values. Marine limestones related to transgression clearly postdating gypsum deposition are characterized by the heaviest isotope values ($\delta^{13}C$: -3.6‰, $\delta^{18}O$: -0.4‰), and limestones which are associated with siliciclastic intercalations within gypsum, thus indicating interfingering of mineralogic facies in the marginal zone, as well as limestones filling the karst cavities in gypsum are lighter ($\delta^{13}C$: -6.5‰, $\delta^{18}O$: -3.5‰). In comparison to those both groups, post-gypsum limestones are clearly lighter ($\delta^{13}C$: -27.9‰, $\delta^{18}O$: -8.6‰).

CARBONATE ECOSYSTEMS: SHALLOW-WATER DEPOSITIONAL PATTERNS AND SEDIMENT EXPORT DYNAMICS

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Present day shallow-water carbonate platforms show significant lateral variations in the continuity of their facies belts. The presence of a barrier versus more open ocean systems ultimately will determine sediment export variations of the individual carbonate ecosystems. The present-day barrier reef systems of the Great Bahama Bank (Caribbean), Belize (Caribbean) and Mayotte (Indian Ocean) show sediment distributions influenced by (i) tidal currents, (ii) prevailing wind direction, and (iii) variations in the morphology of the underlying Pleistocene morphology. Other important factors that might influence facies variations on shallow-water carbonate platforms are linked to the geographic position of the individual carbonate ecosystem, isolated vs. land-attached, ocean currents and associated upwelling and non-upwelling water regimes, trade winds, and tides. Ultimately this will control the type of ecosystem in which there is a dominance of particular sediment producers and associated production of specific carbonate mineralogies and grain-sizes.

The spatial development of recent shallow-water carbonate platforms is reliant on the underlying Pleistocene morphology. Here not only the amplitude of sea level but also the duration, in which sea-level change takes place, will influence lithification and erosion processes of the exposed sediments. Secondly, also the rapidity in which the Pleistocene edifice is reflooded determines whether reef growth results in a closed barrier system, or that certain reef passages remain open. In response, current systems can be reinstalled in the lagoon, which influence carbonate sediment production, grain-size distribution and sediment export. The water circulation will also influence nutrification levels within the lagoon that might affect the carbonate producing biota as observed in the lagoon of La Reunion (Indian Ocean) where coral dominated sediments shift to coralline algae dominated sediments. This shift resulted in a decrease in sediment production and in a prevalence of very fine sand to mud sized grains over medium to fine sands in the nutrient-enriched areas. The difference in grain-size probably originated from a decrease in grazing activity in the nutrient-enriched areas. In time the change in the grain-size spectrum within the lagoon might result in a change in sediment export.

At present it is still underestimated how well variations in facies distributions are reflected in sediment export variations of carbonate platforms. For example the switch in the Pliocene of the Bahamas from a skeletal to a non-skeletal dominated shallow-water system as well the increase in mud production after the sea-level amplitude change at marine isotope stage 11-10 is well reflected in the carbonate platform sediment export. Detailed analysis of sediment export products will not only help to understand evolution of shallow-water carbonate ecosystems in more detail, but also will help to determine variations in space and time within the shallow-water realm.

ARCHITECTURAL ELEMENTS AND SEISMIC FACIES OF SUBMARINE CHANNELS, BROWSE BASIN, NW AUSTRALIA

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Submarine canyons are widely distributed on modern carbonate platform slopes, but relatively little is known about their occurrence on ancient slope systems. Conventional 2D grids often lead to a spatial aliasing whenever the size of submarine gullies and canyons is less than the spacing of the grid. Most studies of modern submarine canyon systems therefore rely on multi-beam bathymetric and sidescan sonar data combined with 2D seismic profiling. This means that although the surface morphology is often very well resolved, the sub-seabed stratal geometries are less clear, preventing a rigorous stratigraphic analysis of canyon evolution through time. In contrast, high-resolution 3D seismic data constitute stacked examples of paleo-seafloors, which are ultimately comparable in resolution to those achieved by multi-beam bathymetry of the present seafloor.

Seismic data from the western part of the Browse Basin, North West Shelf, Australia, reveal the internal geometry and depositional history of a progradational Eocene-Miocene carbonate shelf. The prograding slope system is superbly imaged by two adjacent, three-dimensional multichannel seismic volumes embedded in a two-dimensional multichannel seismic grid. Based on this data, the three-dimensional stratal architecture of prograding clinoforms can be mapped throughout an area of ~ 1000 km^2. The Eocene-Miocene slope system can be divided into an Eocene clinoform succession strongly prograding towards the northwest, and an Oligocene to Late Miocene progradational to aggradational clinoform sequence. The prograding clinoforms of the Eocene succession progressively develop highly dissected, gullied foresets. In contrast, the Oligocene to Late Miocene system is characterized by relatively smooth foresets that lack major incisions. The spatial control provided by the 3 D seismic volume supports a detailed analysis of the relationship between the overall morphology of carbonate systems and the erosion mechanisms on their foresets. This will contribute to a better understanding of calciclastic submarine slope systems.

CARBONATES AND EVAPORITES OF THE SURFACE PIERCING SALT DOMES OF THE GHABA SALT BASIN, INTERIOR NORTH OMAN

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Six surface-piercing salt domes of interior north Oman provide unique insights into the dynamics of the Late Neoproterozoic to Early Cambrian Ghaba Salt Basin. The salt domes are composed of numerous isolated carbonate blocks (so-called 'stringers') and associated evaporites. The salt domes possibly are an important outcrop analogue for intra-salt hydrocarbon plays in the deep subsurface (3-6 km) of the South Oman Salt Basin, which is located around 500 km to the SW of the Ghaba Salt Basin .

The salt dome carbonates include a succession of basinal laminated mudstones to peritidal thrombolites and hence comprise the same lithologies as in the South Oman Salt Basin. The individual 'stringers' in the salt domes are up to 40 meters thick with a lateral extend of several hundred meters. Salt diapirism has lead to strong deformation of the carbonate blocks. This is indicated by a number of deformation structures such as isoclinal folds, cataclasites, thrust faults and dilational breccias. Maturity analyses of solid bitumen, which occurs in laminated carbonates at pore throats and stylolites, indicate a range of burial paleo-temperatures between 100–200°C. This broad range in paleo-temperatures shows that the individual carbonate blocks were buried at least to a depth of six kilometres (assuming a geothermal gradient of 30°C/km). During the subsequent rise of the salt diapirs, intense near-surface dissolution of salt may have led to the chaotic juxtaposition of the 'stringers'. In one of the domes several outcrops are characterized by white dolomite veins displaying the so-called "zebra" fabric. A combination of XRD and SEM analyses demonstrates that these veins are associated with magnesite, siderite, fluorapatite and barite which points to a phase of hydrothermal alteration. Similarly an influence of hydrothermal alteration on solid bitumen maturation was also proposed for the South Oman Salt Basin (Schoenherr et al., in press).

The geological evolution of the carbonate stringers in the Ghaba Salt Basin is thus comparable to the evolution of the deeply buried intra-salt carbonates of the South Oman Salt Basin. The surface-piercing salt domes hence form a suitable analogue to the deep intra-salt hydrocarbon plays of the South Oman Salt Basin.

Schoenherr, J., Ralf Littke, Janos L. Urai, Peter A. Kukla 4 Zuwena Rawahi (in press): Polyphase thermal evolution in the Infra-Cambrian Ara Group (South Oman Salt Basin) as deduced by solid bitumen maturity. – Organic Geochemistry.

SEDIMENTOLOGISCHE STUDIEN IM NORDWESTLICHEN TAUERNFENSTER ERMÖGLICHEN EINE PARALLELISIERUNG VON TEKTONISCHEN EINHEITEN IM TAUERNFENSTER

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Durch Neukartierung des nordwestlichen Tauernfensters seitens der Geologischen Bundesanstalt wurde es möglich, bislang unterschiedlich bezeichnete, aber prinzipiell gleichzustellende tektonische Einheiten zu parallelisieren.

Sedimentologische Charakteristika

Subpenninikum

In der subpenninischen Wolfendorndecke kann ein sedimentärer Verband zwischen dem oberjurassischen Hochstegenmarmor und der Kaserer Fm. nachgewiesen werden. Diese Grenze belegt einen Wechsel des sedimentären Environments von reiner Karbonatsedimentation hin zu klastischen Sedimenten der Kaserer Fm. Carakteristisch für die Kaserer Fm. sind Breccien mit permotriassischen Komponenten, Granitgeröllen und Arkosen. Die Sr-Isotopenverhältnisse von Marmorlagen in den klastischen Sedimenten lassen auf ein Unterkreidealter, wie von Thiele (1980) postuliert, schließen.

Die Bündnerschieferentwickelung im nordwestlichen TF

In den liegenden Anteilen der Bündnerschiefer (BS) sind Kalk-Chloritschiefer, mit bis zu Zehnermeter mächtigen Schollen (Olistolithe) vorzufinden. Erstmals konnten Granitgerölle mit einem Durchmesser von bis zu 0,5 m gefunden werden. Diese Bündnerschiefer enthalten reichlich Schwarzphyllite und wenige Metabasite (massige Metagabbros und/oder Metabasalte). Ein jurassisches Alter dieser Metabasite und auch der Phyllite wird angenommen.

Modereckdecke s. str. (MD)

Die Modereckdecke s. str. des mittleren TF weist ein kristallines Basement auf. Darüber folgen permomesozoische Metasedimente, sehr klastikareiche Bündnerschiefer mit Arkoselagen und polymikten Dolomitbreccien. Lithologisch sind die Arkosen und Breccien völlig identisch mit jenen der Kaserer Fm. Die klastikareichen Bündnerschiefer lassen sich mit jenen im nordwestlichen TF sehr gut parallelisieren. Weiters zeigen die basalen Bündnerschiefer des mittleren Tauernfensters gehäuft Schwarzphyllite mit Metabasitkörpern, die jenen des nordwestlichen Tauernfensters bezüglich ihrer stratigraphischen Position und Mineralogie völlig gleichen.

Deckengliederung und Vorschlag einer neuen Nomenklatur

Basierend auf den oben dargestellten lithofaziellen Charakteristika sind die tektonischen Einheiten paläogeographisch am europäischen Kontinentalrand anzusiedeln. Es kann eine Faziesverteilung von proximaler zu distaler Fazies festgestellt werden, wobei die Kaserer Fm. samt Basis den proximalen und die Bündnerschiefer des NW Tauernfensters den distaleren Faziesraum repräsentieren. Die Bündnerschiefer des NW Tauernfensters werden demnach zur subpenninischen Modereckdecke gestellt.

Thiele, O., 1980: Das Tauernfenster. – In: Oberhauser, R. (Ed.): Der geologische Aufbau Österreichs, 300–314.

LOCALIZED CEMENTATION OF CARBONATE-LITHIC ROCKSLIDE DEPOSITS: PREREQUISITE TO ^{234}U/^{230}TH PROXY-DATING THE MASS-WASTING EVENT

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Carbonate-lithic rockslide deposits are locally lithified by calcium carbonate cements that can be used for ^{234}U/^{230}Th proxy-dating the mass-wasting event.

Age determination of rockslides traditionally is done by ^{14}C-dating of organic remnants that (1) are present in sediments overridden by the rockslide (maximum 'half-bracket age' of event), (2) are trapped within the rockslide debris (proxy for event age), and (3) that were deposited in rockslide-dammed backwater deposits or lakes situated atop the rockslide mass (minimum 'half-bracket age' of event). Since the last 10–15 years, surface exposure dating of detachment scarps and rockslide boulders by cosmogenic radionuclides (CRN) provides an ideal method to directly date the mass-wasting event. Ages deduced by CRN are analytically laborious and, in some cases, still are fraught with substantial 2σ-error ranges. During investigation of the Fern Pass rockslide, Austria (Prager et al., 2006a), portions of the deposit were found cemented by aragonite and calcite. An early aragonite cement was dated to 4150 ±100 yrs by the ^{234}U/^{230}Th disequilibrium method (Ostermann et al., 2007). For the Fern Pass rockslide, two ^{36}Cl exposure data of the detachment scar fully overlap with this age (Prager et al., 2006b). For this rockslide event, the determined ^{234}U/^{230}Th age is the most precise proxy age thus far. Combining the 'directness' of exposition dating with the precision, rapidity, comparatively low cost and easy field sampling of U/Th dating may be ideal to achieve better age determination of mass-wasting events.

Localized cementation is fairly common in carbonate-lithic sturzstrom deposits. Carbonate-rock flour produced by dynamic disintegration during rockslide movement undergoes vadose dissolution, followed by nearby reprecipitation as cement in near-surface levels of the rockslide mass. Because rock flour is most abundant and most reactive immediately after the event, the U/Th age of early-formed cements should be close to event age in most cases. Alternatively, the rockslide mass is percolated deeper within by groundwater, resulting in precipitation of cement in deeper levels in the deposit. Both styles of cementation are not mutually exclusive. The approach to proxy-date rockslides by the U/Th method seems promising. Excavation of comparatively small cement-bearing samples for U/Th dating is easy, and dating can be conducted fairly rapidly and inexpensive. The U/Th approach thus may be particularly suited for proxy-dating carbonate-lithic rockslides of remote locations.

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SR-ISOTOPE CHEMOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF LATEST CRETACEOUS CARBONATE PLATFORMS IN THE CENTRAL-EASTERN MEDITERRANEAN AND MIDDLE EAST

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A precise history of the demise of the characteristic Late Cretaceous rudist formations in the central-eastern Mediterranean and Middle East has not yet been established, because their evolution is rather imprecisely constrained by biostratigraphy of typical carbonate-platform biota such as benthic foraminiferas and calcareous algae, particularly in restricted inner-platform environments. We use Sr-isotope stratigraphy to derive numerical ages for species-rich rudist associations at several localities of the Apulian platform (SE Italy), the Arabian Peninsula (Oman), and SE Turkey to constrain the stratigraphical ranges of characteristic rudist species, and to calibrate the ranges of benthic foraminifera and calcareous algae with chronostratigraphy.

The preferred sample material for Sr-isotope analysis is low-Mg calcite from the outer shell layer of rudists. This material has a been shown previously to have a high potential to have retained the original Cretaceous seawater composition. Concentrations of Sr, Mn, Fe, and Mg and and stable isotope ratios ($^{18}O/^{16}O$ and $^{13}C/^{12}C$) are analyzed to assess a possible diagenetic overprint of the original seawater Sr-isotope ratio of the sampled material.

Our results show that species-rich rudist associations of the Apulian carbonate platform (Salento, SE Italy) range into the latest Maastrichtian (< 66.8 Ma). The same age has been obtained for similar deposits exposed on the Ionian Islands (Greece). Both localities represent high-energy outer margin depositional environments.

In Oman (Qalhat, Sur region), a continuous Cretaceous /Palaeogene sequence of platform carbonates has been studied that represents a small, isolated carbonate platform with normal marine conditions. The Sr-isotope values of rudist shells indicate the latest Maastrichtian, and benthic foraminifera and calcareous algae delimit the position of the K/P boundary a few meters above the last occurrence of moderately species-rich rudist associations. Ongoing studies are aiming at the detailed assessment of environmental change during the K/P transition. This is challenged by dolomitization of the critical boundary interval.

Considering additional published data on latest Maastrichtian rudist associations, a stepwise extinction or reduced diversity is not evident. The few localities representing open marine platform margin environments have highly diverse rudist associations, while species-poor formations are generally from restricted inner-platform environments.

POSSIBLE FEEDBACK MECHANISMS BETWEEN EROSION AND TECTONICS IN OROGENIC SYSTEMS

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Conceptual studies proposed a close linkage between lithosperic processes and surface erosion during the evolution of orogens. The sensitivity of erosion to tectonics (and vice versa) is particularly acute in active orogens, where accretion of lithospheric material leads to self-similar growth of a critical wedge at a rate that is controlled by the relative importance of crustal accretion and surface erosion. An increase in crustal accretion rates at constant erosion rates, for instance, will perturb this balance, causing the orogenic fronts of a critical orogen to shift towards more distal sides, and initiating a vertical growth of the topography in order to keep the critical self-similar geometry. Because of the vertical growth of topography, erosion rates and exhumation rates will increase and then remain at constant, but higher magnitudes. A similar effect, but with a substantially different exhumation pattern, yields a decrease of erosion rates at constant rates of crustal accretion. The response of a critical orogen to such a perturbation is a lateral self-similar growth. However, in contrast to the previous example, the erosional flux will first decrease, and then increase to the magnitudes prior to the perturbation. This increase occurs because erosion operates at a successively larger surface as the orogen widens. The orogen will enter a stable and steady situation when the accretionary flux will be balanced by the erosional flux. Note, however, that at this new stage exhumation rates will be lower than prior to the perturbation. Hence, the response of a climate-driven lateral growth of a critical orogen is a change from predominantly vertically- to laterally-driven exhumation. In a final case, an increase in the erosional flux larger than the accretionary flux will destroy the critical topography, leading to a smaller active wedge where deformation focuses in the core of the orogen to restore the critical taper. The result is a change towards a more vertically-directed exhumation in the orogen core.

This conceptual model potentially explains three major stages in the evolution of the Swiss Alps. The *first stage* between ca. 35 and 20 Ma is considered to represent the response to the indentation of the Adriatic promontory of the African plate into the interface between the upper and lower crust of the European continental plate. The result is a net accretion of crust into the orogen and a predominantly vertical growth of the Alpine edifice and the topography. The response on the surface was an expansion of the drainage network towards the rear of the orogen and downcutting. The data that is consistent with this interpretation is an increase in sediment discharge, a shift in the petrographic composition of conglomerates towards more crystalline constituents with sources in the rear of the Alps, lateral coalescence of alluvial fans, and high exhumation rates indicating a vertically-directed exhumation. The *second stage* started in the Burdigalian and lasted until the end of the Miocene. It is characterized by a lateral expansion of the wedge by ca. 100% as the southern Alps and the Jura mountains became incorporated into the wedge. This growth of the deforming wedge was associated by a decrease of exhumation rates and sediment flux. It implies a change from predominantly vertically-directed exhumation to lateral extrusion. Because the distal shift of the deformation fronts also enhanced the area on which erosion operated (though at lower magnitudes), sediment flux most likely increased until accretionary flux was balanced by the erosional flux. This appears to have been the case at end of the Burdigalian when the erosional flux reached similar magnitudes as at the end of the Aquitanian. The *third stage* of Alpine development started in the Late Miocene or early Pliocene. At that time, thrusts beneath the Po Plain became sealed by undeformed Pliocene, shortening in the Jura decreased, the North Alpine foreland basin became inverted and eroded, and active deformation started to focus in the core of the Alps where Quaternary thrusts were mapped. At the same time, sediment flux from the Alps increased to reach the highest magnitudes since the time of continent-continent collision. It caused the Alps to enter a destructive stage and the locus of active deformation to shift towards to the orogenic core, but it also resulted in a net unloading of the orogen and thus in a flexural rebound of the foreland plate.

300 MILLION YEARS OF BASIN EVOLUTION: BURIAL, EXHUMATION AND EROSION OF THE UKRAINIAN DONBAS

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The Ukrainian-Russian Pripyat-Dniepr-Donets Basin is a large intracratonic rift structure formed during the Late Devonian. It is situated at the southern margin of the Precambrian East European Craton, adjacent to the Hercynian Tethyan belt in the Black Sea area and the Alpine Caucasus orogen. With a sediment thickness of up to 20 km, it is one of the deepest sedimentary basins of the earth. The eastern part of the Pripyat-Dniepr-Donets Basin – called Donbas foldbelt – is strongly folded and inverted. Its structure is characterised by WNW-ESE trending folds including the Main Anticline, a prominent, almost symmetrical fold with steeply dipping limps, situated above the former rift axis. The exact timing of inversion is still under debate, but may have taken place during a major erosion period during the Permian, or in response to Alpine tectonics during the Late Cretaceous to Early Tertiary. The structure of the Donbas foldbelt was recently investigated by seismic reflectance and refraction in the frame of the international collaborative DOBRE project, revealing that inversion occurred at the crustal scale as a mega-pop-up, which involved a major detachment fault through the entire crust and an associated back-thrust.

For this study we combined fission track analysis and vitrinite reflectance measurements along two profiles following the DOBRE transect across strike and the Main Anticline along strike. Our goal is to gain insights into the thermotectonic evolution associated with burial, exhumation and erosion of the Donbas foldbelt, particularly with respect to the timing of basin inversion and formation of the Main Anticline. Our data revealed that maximum burial was reached during the Sakmarian (ca. 275 Ma), followed by a major erosion period during the Late Permian, probably related to the build-up of stress emanating from the Variscan Caucasus / Uralian orogens. The extent of Permian erosion, however, was less pronounced than previously assumed, and net Permian erosion of the Ukrainian shield was certainly less than the 10 km suggested by Stovba and Stephenson (1999). During the Early Triassic, parts of the basin were affected by a thermal event with heat flows up to 200 mW/m^2, probably related to Triassic igneous and also extrusive magmatic activity. No significant burial or erosion affected the south-western margin of the basin after the Late Triassic, implying that this part of the basin remained tectonically quiet. The formation of the Main Anticline can be placed between Permian main coalification and the Late Cretaceous and was probably associated with Cimmerian compression during the Late Triassic / Early Jurassic, corresponding to the first stage of basin inversion. Parts of the basin were also affected by a Late Jurassic thermal overprint related to magmatic activity. During the Late Cretaceous (~70 Ma) the main basin axis was tilted and exhumed, resulting in a second major erosion period and the second stage of basin inversion.

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SEDIMENTOLOGICAL AND CHRONOLOGICAL INVESTIGATIONS OF DEBRIS FLOW EVENTS AND THE ASSOCIATED SEDIMENT DYNAMIC OF THE ALPINE LAKE PRAGSER WILDSEE (LAGO DI BRAIES)

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The lake Pragser Wildsee is a high elevated lake (1492 m a.s.l.) in the Dolomites (N-Italy). In former studies (Irmler 2003, Irmler et al. 2005, 2006) the lake sediments of the Pragser Wildsee were used to reconstruct the debris flow frequency of the last millennia by varve counting to generate a detailed debris flow calendar for the last 8000 years. From different problems detected during these first studies it was obvious that it is necessary to have a detailed understanding of nowadays processes which affect the formation of annually laminated sediments and the event layers (debris flow, high flood, avalanches) in between.

So the current study primarily focuses on the recent to sub-recent sediments in order to understand the impact of sedimentation and erosion processes within the catchment area of the lake but also within the lake itself throughout the year. For these purposes two sediment trap systems including temperature sensors were installed in the Pragser Wildsee. During the ice-free period (May-October) samples will be collected every month to differentiate the processes and to quantify the sediment load. The temperature sensors yield detailed information about processes in the lake, such as thermal stratification which strongly influences the type of sedimentation. From samples of the sediment trap first thin sections have been prepared in order to analyse structure and composition of the sediments. The results are compared with thin sections of gravity and piston cores with the aim to understand the various processes that play a role for the formation of varve and event layers. Furthermore these information will be used together with the analysis of thin sections of two piston cores to generate a composite profile which will remarkable enhance the existing debris flow calendar.

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