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Laureline SCHERLER (2011)

**Terrestrial paleoecosystems of large mammals  
(Tapiridae, Anthracotheriidae, Suoidea) from the Early  
Oligocene to the Early Miocene in the Swiss Molasse  
Basin: biostratigraphy, biogeochemistry,  
paleobiogeography and paleoecology**  
(217 pp.)



## ABSTRACT

Organization of the continents, geography, climates, and environments are in constant evolution since mists of time, influencing the vegetal and animal communities. Thus, Europe was highlighted by important changes during the Cenozoic, and particularly in the Oligocene and the Early and Middle Miocene (34–15 Ma).

Hoofed mammals (perissodactyls and cetartiodactyls) probably emerged in the Middle Eocene in Southeast Asia. Early migrations occurred rapidly: first towards North America through the Bering Strait and towards Europe as soon as the Turgai Strait closed, then towards Africa when emerged land-ways appeared due to the collision between the African and Eurasian tectonic plates.

One of the most important faunal event in Europe occurred in the Early Oligocene. It is known as the “Grande Coupure” and was described for the first time by Stehlin in 1909. During most of the Eocene, Europe was an isolated continent that was separated from North America and Asia by deep-water basins. In the latest Eocene, a strong drop of the global sea-level occurred due to a major glaciation in Antarctica. The closure of the Turgai Strait allowed the Asian fauna to spread towards Europe, replacing the endemic mammalian communities of Europe.

During the Oligocene, the climate was quite stable and only few faunal variations are documented. Nevertheless, a strong decrease in diversity of the large terrestrial herbivores (e.g., rhinocerotids, anthracotheriids, ruminants) occurred at the Oligocene–Miocene boundary. In the Early Miocene, continents began to move and Africa, which was isolated during the Oligocene, re-connected to Eurasia thanks to tectonic processes. Many faunal interchanges occurred since the end of the Early Miocene, and successive extinctions and renewals were observed in Europe since the Burdigalian. One of these events, described for the first time by Van Couvering and Berggren in 1977 and named the “Proboscidean Datum Event”, highlighted the appearance of the first proboscideans (elephants) in Europe.

The Swiss Molasse Basin recorded many mammalian fossils, and the micro-faunas were well studied and described, allowing the establishment of a biostratigraphic chart. Most Tertiary fossiliferous localities in Europe could thus be precisely dated. Unfortunately, fossils of large mammals were never or rarely re-

studied since their discovery at the end of the 19<sup>th</sup> / beginning of the 20<sup>th</sup> century. The Swiss rhinocerotoids were reviewed by D. Becker in 2003, and later a project of the Swiss National Foundation was established (n°126420) for two PhD students, B. Mennecart and myself, to reassess the large terrestrial herbivores of the Swiss Molasse Basin. Tapirids, anthracotheres, and suoids are the subject of this thesis, whereas the ruminants and cainotheres are studied by my colleague.

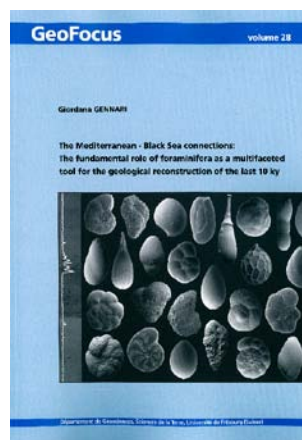
Tapiridae, Anthracotheriidae, and Suoidea are reviewed, and new diagnostic characters are established. Species of *Protapirus* (Tapiridae, Perissodactyla, Mammalia) are more precisely defined based to the presence or absence of a lingual pseudofossa on the upper premolars. Anthracotheres of the subfamily Anthracotheriinae (Anthracotheriidae, Cetartiodactyla, Mammalia) that were until now gathered into the single genus *Anthracotherium* are separated into two taxa, with the creation of the new genus *Elliottherium* and the new species *Elliottherium murphyi*. This latter genus can be differentiated from *Anthracotherium* by the absence of an isolated entoconulid on m3, a postprotocrista that does not join the premetacristule but is distally directed and isolated on upper molars, and by only slightly reduced lateral metapods in respect to the median ones.

Two hundred and fifty-three European localities (Austria, Bulgaria, Czech Republic, France, Germany, Great Britain, Greece, Hungary, Italy, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Switzerland, Turkey) that recorded fossils of these three groups are indexed in this study and around 600 remains of tapirs, anthracotheres, and suoids are described. This allowed the establishment of very precise biostratigraphic ranges for the different species from the Late Eocene to the Middle Miocene in Europe. These new data highlighted many faunal interchanges as well. Indeed, the event of the middle part of the Rupelian (RFT, "mid-Rupelian Faunal Turnover") is described for the first time, at least at the level of the large terrestrial herbivores. Furthermore, six successive events of specific extinctions, speciations and/or emergences are described very precisely (ETOFE-1 to 6, "European Terminal Oligocene Faunal Events"). Finally, the multiple events linked to the "Proboscidean Datum Event" are observed and commented. This work demonstrates that most of the faunal changes occurring in Europe during the Oligocene and the Early and Middle Miocene coincided with the major glaciations in Antarctica.

To conclude, the extinction of anthracotheres in Europe since the latest Oligocene can be partly explained by the aridification of the environments. Indeed, anthracotheres lived probably in swampy areas and the opening of the habitats and the aridification of the climate must have been fatal to this mammalian group. On the other hand, tapirs seemed to have taken profit of this ecologic change in the Early Miocene, as their diversity increased during this time. Tapirs, being folivorous browsers, were dependent on the availability of having "fresh food" year-round. This could indicate that seasonality in the Early Miocene was not as strong as it was later in the Middle Miocene, when primitive tapirs temporarily disappeared from Europe. Finally, the increasing diversity of the pigs was probably caused by the massive and successive dispersal of African faunas in Europe during the events of the Middle Miocene. Additionally, this group with great adaptive ability could also have taken advantage of the ecological niche freed by the disappearance of the tapirs in the Middle Miocene.

Girodana GENNARI (2011)

The Mediterranean – Black Sea connections:  
The fundamental role of foraminifera as a multifaceted  
tool for the geological reconstruction of the last 10 ky  
(171 pp.)



#### ABSTRACT

This research focuses on the Late Pleistocene-Early Holocene paleoceanographic history of the Eastern Mediterranean Sea and of its easternmost connection, the Tethyan relict basins (e.g., the Black Sea). It aims to document, date and possibly quantify paleoclimatic and paleoceanographic changes by using a multidisciplinary approach based on biological and geochemical proxies from deep sea, shelf areas and continental archives. This multi-proxy study includes micropaleontological studies of benthic and planktonic foraminiferal assemblages from cores and the geochemical study of phosphorus, organic matter, and major and minor elements distribution (by  $\mu$ -XRF scanning) in sediments, as well as AMS- $^{14}\text{C}$  dating to achieve the chronological framework.

The Mediterranean Sea is a complex system subdivided in several basins interconnected by straits and sills and is an ideal recorder of past climate variability; thus it provides a natural laboratory for paleo/environmental studies.

In particular, the Eastern Mediterranean Sea is characterized by the occurrence of organic matter-rich layers, termed sapropels, intercalated in normal hemipelagic sediments. The origin of such layers is still highly debated and is possibly related to significant changes in climate, water circulation and biogeochemical cycling (e.g., Rohling, 1994 and references therein). According to the “stagnation/anoxia” model, sapropel formation is linked to water column stratification induced by fresh water input, which prevents vertical mixing and promotes bottom water anoxia (e.g., Rohling and Hilgen, 1991). In the “increased productivity” model, it is instead due to enhanced productivity in the euphotic zone, resulting in enhanced organic matter flux to the sea floor (e.g., Calvert, 1983). More recently, a Black Sea outflow has been considered as the possible cause for the water column stratification that led to bottom water anoxic conditions and formation of Sapropel S1 (around 9 kyr) in the Eastern Mediterranean Sea (Aksu et al., 2002a). Regardless of the mechanism that led to their formation, sapropels occurrence is cyclic and it is thought to be linked to minima in the precession cycle, corresponding to Northern Hemisphere summer insolation maxima, with a periodicity of about 21 kyr (e.g., Rossignol-Strick, 1985).

The study of major and minor element distributions and solid phase phosphorus content in a Late Pleistocene-Holocene sediment core from the Cretan Ridge provided evidence of enhanced delivery from land during sapropel S1 deposition and of enhanced regeneration of phosphorus (i.e., nutrients) relative to carbon under low-oxygen conditions. Furthermore, Fourier analysis on the ultra high resolution  $\mu$ -XRF data revealed for the first time frequencies that have been provisionally assigned to high frequency millennial to decennial-scale solar cycles (centred at 1700, 550, 210, 85–70, 60 and 50 years), thus confirming the strong sensitivity of Mediterranean climate even at a decennial scale.

Since a causal link between the outflow of Black Sea waters into the Eastern Mediterranean and the deposition of sapropel S1 has been recently proposed (Aksu et al., 2002a), the nature and timing of the re-establishment of an efficient connection between these two basins has also been explored.

For these reasons, several gravity cores retrieved on the South-western Black Sea shelf (Bosporus outlet) were studied. The results obtained so far added a significant piece to the overall complex scenario of the

Mediterranean-Black Sea connection's history, mainly in term of better defining its much controversial chronology. Radiocarbon dating on bivalves' shells from gravity core MedEx05-13, retrieved during the 2005 *R/V Mediterranean Explorer* Black Sea Expedition, provided an age of about 7.5 <sup>14</sup>C ka BP for the sediments immediately overlying the unconformity surface identified during the survey, which has been interpreted as a subaerial erosional surface. All the sediments belonging to the unit overlaying the unconformity show ages younger than 7.5 ka BP ("post-flood" marine stage) and a comparable  $\mu$ -XRF geochemical signature, while the sediments below display ages > 50 ka BP. The results achieved by this study are then well in agreement with the Black Sea flooding hypothesis by Ryan et al. (1997) that suggests an abrupt inflow of Mediterranean waters in its eastern basin at around 8.4 ka BP. The "post-flood" benthic foraminiferal assemblages are characterized by a low species diversity of general Mediterranean affinity and are dominated by species belonging to the genus *Ammonia*.

Decades of study of the Eastern Mediterranean Sea have shown that changes in insolation in the Mediterranean and northern African region directly influence its sedimentation, as has been proved for sapropel formation (e.g. Rossignol-Strick, 1985). To better understand the interplay and dynamic link between the North Atlantic/Siberian pressure system and the African/Asian monsoon that have been proved to play an important role for the Mediterranean paleoclimate and paleocirculation (e.g., Rossignol-Strick, 1985), early Holocene lacustrine sediments from the Arabian peninsula were studied. In this case, benthic foraminifera, together with other microfossils such as carophytes, provided evidence of a Holocene pluvial phase that led to the development of a temporary lake as a consequence of enhanced precipitation. Radiocarbon dating allowed to link the lake development and the consequent foraminiferal colonization to a well documented pluvial period that interested the Arabian peninsula between 10.50 and 6.5 ka BP (e.g., Fleitmann et al., 2007), thus corresponding to the period of enhanced Nile river runoff that has been proposed as a cause of the water-column stratification – and possibly sapropel S1 formation - in the Eastern Mediterranean Sea.

Due to the Mediterranean complex morphology and circulation pattern, basinal-scale events as well as regional climate changes have been registered in different ways according to local geographical settings (i.e., sub-basins), thus resulting in differences in the sedimentary record. To better understand the Holocene paleoceanographic evolution of the Mediterranean Sea, part of this research focused also on the Westernmost Mediterranean Sea.

The Alboran Sea is characterized by the presence of several active and inactive cold seeps-related features such as mud volcanoes and pockmarks, which were documented for the first time in 1999 (TTR-9 Leg 2). Since then, different research cruises focusing on the area (TTR-12, TTR-14, TTR-16 and TTR-17) contributed to a better knowledge of the so-called "mud diapir province".

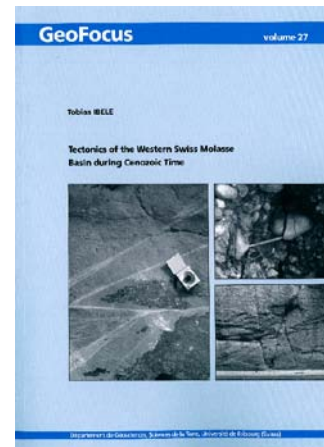
The micropaleontological study of the hemi-pelagic sediments on top of Maya and Dhaka Mud Volcanoes (MV) has shown that the extruded mud breccia provided a suitable substratum for the colonization and development of cold-water corals and associated ecosystems. At both locations, the cold-water corals development is related to high nutrient availability, triggered by upwelling and/or strong currents that mobilized the nutrient horizontal fluxes. These intervals are characterized by high abundances of the planktonic foraminifera *N. incompta*. The shift from the *N. incompta* to the *G. inflata* dominated period, which corresponds to the decline of the coral ecosystem, reflects more modern paleoceanographic conditions and a deep pycno-nutricline; it seems to co-occur with a shift from wet to arid conditions, at the end of the African Humid Period (~ 7.6 ka BP at Maya MV) and at the beginning of a more complex human society impact along the Mediterranean coasts (~ 2.2 ka BP Dhaka MV). Carbon isotopes analysis on benthic foraminifera excluded the influences of hydrocarbon seepage at both Maya and Dhaka mud volcanoes.

The mud breccia sediments retrieved at the two aforementioned mud volcanoes (Maya and Dhaka MVs), as well as the one cored on a northern site (Carmen MV), were analysed for their micropaleontological content, since such extruded sediments are supposed to originate in the Alboran basin lowermost sedimentary sequence and represent then a "window" on the deep sea subfloor. At the Dhaka MV the mud breccia matrix results to be mostly composed by mixed Late Cretaceous (Lower and Late Maastrichtian), Miocene (generally Serravallian), and Pliocene planktonic foraminifera, while Late Cretaceous forms are dominant at Maya MV. At Carmen MV the mud breccia contains dominant planktonic foraminifera from Zones N8-N10 (Middle Miocene). Based on these observations, the lowermost olistostromic sedimentary unit present in the Alboran Sea and documented in Jurado & Comas (1992) is identified as the main source of the extruded material at all the studied mud volcanoes. The age difference in the source sediments is possibly due to the presence of olistoliths of different age in the main olistostromic complex.



Tobias IBELE (2011)

Tectonics of the western Swiss Molasse Basin during  
Cenozoic Times (166 pp.)



#### **ABSTRACT**

The western Swiss Molasse Basin is a flexural foreland basin that presently is in a wedge-top position above a décollement formed in Triassic evaporites near the base of the underlying Mesozoic units. In front of the western Swiss Molasse Basin, the décollement tectonics led to folding and thrusting of the Jura Mountains. The latter are widely accepted to represent the thin-skinned foreland fold-and-thrust belt of the central Alps. In contrast to the Jura Mountains, the western Swiss Molasse Basin lacks larger tectonic structures. Folds are very low in amplitude and strike-slip faults are known only locally. It nevertheless can be considered as part of the foreland fold-and-thrust belt, since it sits on top of the same detachment and since the boundary to the Jura Mountains is an erosional contact only. The boundary to the Alpine orogenic wedge s.s. is marked by the basal thrust of the Subalpine Molasse, representing a shallower and more internal detachment at the base of the Tertiary units.

This study investigates the deformation of the western Swiss Molasse Basin in the larger Canton Fribourg area. Based on structural field work, it shows that in addition to low amplitude folding, the western Swiss Molasse is affected by strike-slip deformation in a general NW-SE compressional stress field. The mapped structures are fractures, slickensides, brittle deformation bands and faults as well as pressure solution pits on surfaces of conglomerate pebbles. The deformation is examined in terms of mechanics, geochemistry and its impact on regional tectonics.

Deformation in the sandstones initiates with the formation of brittle deformation bands. The operating mechanism is grain crushing, porosity reduction and interlocking of grain fragments along planar zones. The interlocking leads to strain hardening, so that ongoing deformation forms new subparallel bands. Microscopic investigation of the brittle deformation bands from the Molasse show that fault gouges develop in the bands following the initial grain crushing. In these micro-fault gouges, regular foliation structures develop in alternation with chaotic structures, implying a cyclic change in deformation mode from instantaneous fracturing to continuous shear, i.e. from seismic to aseismic faulting on the micro-scale. The foliations are composed of fibrous palygorskite, a Mg-rich clay mineral that forms in the course of deformation. In contrast to grain interlocking, the appearance of palygorskite causes strain softening and hence strain accumulation in the fault gouges of the bands.

X-ray diffraction analyses of fault gouges and host rock samples as well as electron dispersive spectroscopy of micro-fault gouges from brittle deformation bands revealed that palygorskite is common in fault zones on every scale, but absent in the host rock. Equilibrium calculations carried out with the host rock mineralogy and a variety of formation waters from the region revealed palygorskite to be stable, while chlorite (present in the host rock) is unstable in that configuration and at surface temperatures. This implies a chlorite-consuming reaction for palygorskite formation triggered by deformation, i.e. by contact of the ground material with the fluid phase.

The populations of slickensides and brittle deformation bands mapped at different localities are arranged in pairs with synthetic and antithetic orientation and are interpreted as different shears of a Riedel system. The fractures can be subdivided into mode 1 cracks parallel to  $\sigma_1$  and sheared fractures parallel to the slickenside populations. The mapped faults comprise cataclastic fault cores and damage zones with dense

networks of fractures, slickensides and brittle deformation bands oriented in Riedel-type geometries. The mapped faults rarely exceed one kilometre in length, but individual faults may compose larger fault zones in which shear is distributed. The orientation of the mapped structures is subvertical, and kinematics are left-lateral strike-slip in the case of N-S orientation and right-lateral strike-slip in the case of WNW-ESE to NW-SE orientation. The calculated paleostress is NW-SE compression and uniform throughout the study area. Overprinting relationships show no system, which underlines that deformation is the response to only one stress regime.

The availability of new interpretation of seismic surveys reveals the structures in the deeper levels of the study area, especially fault zones located in the Mesozoic units. While the Tertiary Molasse at the surface shows N-S striking and WNW-ESE striking faults, the Mesozoic units show considerably fewer WNW-ESE striking faults. In addition, the Mesozoic units also show NE-SW striking faults not present in the Tertiary Molasse at the surface. In cross-section, the faults in the Mesozoic units mostly show half-grabens, although offset is partly reverse. Taking into account the regional tilt of the strata towards southeast, N-S striking faults can mostly be interpreted as left-lateral strike-slip faults and WNW-ESE striking faults as right-lateral strike-slip faults. All faults within the Mesozoic level root with listric terminations in the Triassic evaporites. The NE-SW and N-S striking faults are interpreted as former normal faults formed by E-W and NW-SE extension, respectively, that became inverted by NW-SE compression.

The deformation zones derived from surface mapping and the structures revealed by the seismic interpretations are combined in a 3-D kinematic model of the study area. In this model, deformation is characterised by a kinematic decoupling of the Mesozoic and Tertiary levels along Triassic evaporites. In the internal parts a second decoupling is developed at the base of the Tertiary Molasse. It corresponds to the basal thrust of the Subalpine Molasse extending underneath the Plateau Molasse, with a blind end located about 10 km northwest of the most frontal imbricate of the Subalpine Molasse. Interaction of strike-slip faulting in the Plateau Molasse and thrusting at the front of the Subalpine Molasse indicate that deformation in both tectonic units is contemporaneous.

The timing of deformation is poorly constrained by the data. NW-SE compression probably starts with the formation of the Jura Mountains-Molasse Basin foreland fold-and-thrust belt in the upper Miocene. It postdates the Oligocene-Miocene deposition of the Molasse as well as the E-W and NW-SE extension recorded in the Mesozoic units, which most likely took place in the Paleogene. The current seismicity of the region reveals that strike-slip faulting according to NW-SE compression, starting in the Neogene, is still active and partly related to the proposed deformation zones.

Katja VON ALLMEN (2010)

Variations of calcium and barium isotopes and elemental contents in biogenic and abiogenic geological archives (97 pp.)



### Abstract

With the changing climate of present days it becomes increasingly important to understand past climate and climate changes. This can be achieved by reconstructing the changing chemical composition of past ocean water which is in chemical exchange with the atmosphere. Past chemical seawater signals are recorded in various archives such as, e.g., biogenic brachiopod calcite shell material or abiogenic calcite cements. Biogenic brachiopod calcite shell material is relatively resistant to diagenetic alteration. However, the challenges for chemical reconstruction comprise the issue of vital effects present in biogenic shell material overprinting the original chemical composition of the seawater. Although these vital effects can be estimated if modern counterparts still exist, it is unclear if these vital effects remained unchanged over the long evolutionary time of, e.g., the Phanerozoic. Abiogenic material such as calcite cements is free of vital effects and may record chemical signatures in equilibrium with coeval seawater. However, calcite cements may chemically be less stable throughout the process of diagenesis than biogenic calcite.

### Chapter 2

Fossil brachiopod shells were recently used for Phanerozoic calcium isotopic seawater reconstructions and a general  $\delta^{44/40}\text{Ca}$  increase of about 0.7‰ was detected from the Ordovician to the present (Farkaš et al., 2007). However, modern brachiopods are sparsely investigated in terms of calcium isotopic composition. To fill this gap, two modern brachiopod species, *Terebratulina septentrionalis* and *Gryphus vitreus* were thoroughly investigated with respect to calcium, oxygen and carbon isotopic composition. The results reveal relatively small  $\delta^{44/40}\text{Ca}$  isotopic variations within a single shell ranging from 0.16 to 0.33‰. However, the variation between the two species of up to 0.62‰ is large. Oxygen isotopes, on the other hand, are close to the expected equilibrium with seawater. The carbon isotopic composition is extremely variable and seems to be largely affected by vital effects. The  $\delta^{44/40}\text{Ca}$  inter-species variation of up to 0.62‰ is likely caused by vital effects maybe in conjunction to the specialized shell structure of *G. vitreus*. Such a large calcium isotopic inter-species difference can clearly affect the Phanerozoic seawater reconstruction that showed a maximum increase of 0.7‰ (Farkaš et al., 2007).

### Chapter 3

The minor and major elemental composition and oxygen isotopes were investigated in the shells of the two modern brachiopod species *Terebratulina septentrionalis* and *Gryphus vitreus* (the same specimens from chapter 2) at much higher resolution compared to chapter 2. This approach was chosen to reveal the influence of vital effects on the microscale. Contrary to earlier findings by Pérez-Huerta et al. (2008) results indicate that Mg/Ca paleothermometry may not be applicable to brachiopod shells. High-resolution  $\delta^{18}\text{O}$  depth profiles indicate that vital effects do not influence oxygen isotopes in the columnar layer of *G. vitreus*. Sr and Li contents suggest that the columnar layer of *G. vitreus* is closer to abiogenic calcite than the fibrous layers of both species. In general, the investigations reveal that the fibrous layers of both species are more subject to vital effects than the columnar layer of *G. vitreus*. These findings are an important contribution to the ongoing discussion about the most suitable carbonate material for chemical ocean water reconstruction.

## Chapter 4

As demonstrated in chapter 2 vital effects exerted on biogenic carbonates can constrain the chemical ocean water reconstruction. It is thus recommendable to either compare the records of different biogenic archives or to compare biogenic and abiogenic archives in order to detect vital effects.

This chapter investigates the calcium isotopic composition of fossil and modern marine cements and microbial mats in order to establish a new archive for Phanerozoic ocean water reconstruction free of vital effects. Calcium isotopes in cements and microbial mats were generally found to be heavier than published coeval brachiopod data (Farkaš et al., 2007). A large discrepancy between the two archives was detected at the Devonian/Carboniferous transition where cements recorded a much smaller shift in calcium isotopic composition of the seawater (+0.2‰) than brachiopods (+0.5‰). On the basis of Sr/Mg ratios, basin effects of restricted epeiric seas leading to locally chemical distinct seawater signatures can almost certainly be excluded. First calcium isotopic results from Devonian and Carboniferous conodonts support the results yielded by the cements. The discrepancy at the Devonian/Carboniferous transition between the cements and brachiopods could have been caused by a less refined metabolic system during the early evolutionary stage of brachiopods. The metabolic system of brachiopods may have been influenced by the transition of calcitic to aragonitic sea at the Devonian/Carboniferous transition and by the accompanying increase of the Mg/Ca ratio of the ocean water. Such a hypothetical change of the metabolic system of brachiopods could have influenced the uptake of chemical elements and isotopes as well as the secretion of the shell. We propose that calcite cements and microbial mats are more reliable archives than brachiopods for seawater reconstructions. These findings demonstrate that care should be taken when relying on a single archive and emphasize the importance for a multi-archive approach for chemical ocean reconstructions.

## Chapter 5

Results from the previous chapters demonstrate that a multi-proxy approach can allow a critical evaluation of the individual methods. Therefore, this PhD thesis was extended to introduce barium as a new potential proxy in the global cycle.

Elemental barium has a short residence time and is not homogeneously distributed in the ocean. It shows a nutrient-type behavior (Chan et al., 1976). Based on concentration of barium alone it is not possible to decipher the amount contributed by the various possible sources of particulate and dissolved barium to the ocean. In this light it is desirable to prepare the path for barium isotopes applied to the global barium cycle. A new method was set up to analyze barium isotopes in terrestrial samples by multicollector ICP-MS using a  $^{130}\text{Ba}/^{135}\text{Ba}$  double spike technique. As a first approach, several international standards, terrestrial gangue samples, a marine-diagenetic barite and a barite from a collection (probably of marine origin) were analyzed. Furthermore, precipitation experiments were performed to investigate the influence of temperature and precipitation rate on barium isotopes. These first analyses reveal a  $\delta^{137/134}\text{Ba}$  fractionation of up to -0.5‰ relative to the laboratory Ba nitrate standard solution. The most fractionated samples were the barite from a collection and the marine-diagenetic barite, along with the experiments precipitated at slow rates. The results of the former two samples suggest a possible influence of microbial sulfate reduction related to the marine diagenetic environment. The latter result points to fractionation in relation to precipitation rate or aqueous speciation. These results emphasize the utility of applying barium isotopes to the global barium cycle.

This PhD thesis demonstrates the importance of investigating the elemental content and isotopic composition of modern biogenic carbonates such as, e.g., brachiopods in order to understand and correctly interpret fossil analogues. The comparison of different coeval archives and proxies is essential to evaluate their robustness. The approach chosen in this thesis is essential to accurately understand and reconstruct past global changes and to apply the findings to the future.

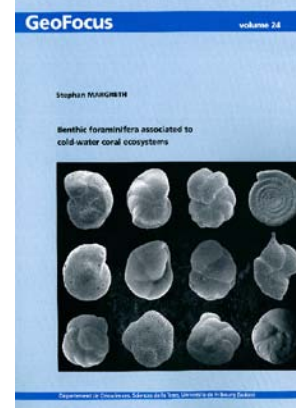
## References

- Chan, L.H., Edmond, J.M., Stallard, R.F., Broecker, W.S., Chung, Y.C., Weiss, R.F., Ku, T.L., 1976. Radium and barium at GEOSECS stations in the Atlantic and Pacific. *Earth and Planetary Science Letters* 32, 258-267.
- Farkaš, J., Böhm, F., Wallmann, K., Blenkinsop, J., Eisenhauer, A., van Geldern, R., Munnecke, A., Voigt, S., Veizer, J., 2007. Calcium isotope record of Phanerozoic oceans: Implications for chemical evolution of seawater and its causative mechanisms. *Geochimica et Cosmochimica Acta* 71, 5117-5134.

Pérez-Huerta A., Cusack M., Jeffries T. E. and Williams C. T. (2008) High resolution distribution of magnesium and strontium and the evaluation of Mg/Ca thermometry in Recent brachiopod shells. *Chem. Geol.* **247**, 229-241.

Stephan MARGRETH (2010)

Benthic foraminifera associated to cold-water coral ecosystems (248 pp.)



### Abstract

Cold-water coral ecosystems dominated by the species *Lophelia pertusa* and *Madrepora oculata* occur worldwide and are especially developed along the European margin, from northern Norway to the Gulf of Cadiz and into the Alboran Sea. Their discovery is a major achievement of the last few decades and their widespread occurrence presents a challenge to understand their development, preservation and possible importance in the geologic record.

On the Norwegian shelf active/living reefs are developed on elevated hard substrata. Along the Irish margin *L. pertusa* builds large fossil or active carbonate mounds. In the Gulf of Cadiz and in the Alboran Sea buried reefs and patch reefs are generally found in association with mud volcanoes. In modern oceans, they provide important ecological niches for the marine benthic fauna in the deep-sea. In comparison to the macrofauna the microfauna, particularly the foraminifera associated to these systems are poorly known. This thesis is a detailed study of the benthic and planktonic foraminifera along the Norwegian margin, in the Porcupine-Rockall region and in the Alboran Sea.

The results of this work show that in the Porcupine/Rockall region benthic foraminiferal assemblages are strictly related to the distribution of facies. On the Norwegian margin, benthic foraminiferal habitats are weakly defined and grade one into the other preventing the sharp facies separation observed along the Irish margin. In the Alboran Sea cold-water coral ecosystems and cold-water carbonate mounds are presently buried and corals are generally fragmented. However, benthic assemblages from coral-rich layers in the Alboran Sea and those from Porcupine/Rockall and Norway show remarkable similarities. In particular, epifaunal-attached species such as *Discanomalina coronata*, *Cibicides refulgens*, and *Lobatula lobatula* dominate the assemblages with *D. coronata* restricted to living cold-water coral reefs facies only in co-occurrence with coral fragments.

In conclusion, cold-water coral ecosystems occur at different latitudes, the associated foraminiferal assemblages are consistent from Norway to the Western Mediterranean. Thus they can be used to identify these ecosystems even in the geologic record, when the corals are often strongly dissolved like in the Alboran Sea.

**Richard WAITE (2010)**

**The palaeoecology of high-spined gastropods and the lost palaeosols: depositional reconstructions on a shallow carbonate platform (Late Kimmeridgian, Swiss Jura Mountains) (149 pp.)**



**Abstract**

The deposits of the Late Kimmeridgian succession of the Swiss Jura Mountains mainly consist of pure, white bioclastic carbonate sands and muds. Within these sediments nerineoid gastropods are common faunal constituents and form recurrent mass accumulations. These metre-thick shell accumulations indicate special bathymetric and ecological conditions, under which the gastropods thrived, and which prevailed for extended periods of time. The mass accumulations are thought to represent a predominantly sessile, suspension-feeding gastropod community colonising stable sediment surfaces on topographical swells under agitated water conditions. Sediment accumulation on the swells was low on behalf of bypass conditions and armoured carbonate build-ups were formed consisting mainly of the interlocking shells of the high-spined nerineoids. Recent large tropical turritellid gastropods of the Indian Ocean are morphologically similar to the Kimmeridgian nerineoids. In the past turritellids formed mass accumulations in carbonate environments although at present mass accumulations are only known from siliciclastic environments. These are predominantly found in cool-water environments associated with high labile organic carbon availability coastward of zones of upwelling. Turritellids may nevertheless be compared to nerineoids. In tropical depositional environments large turritellids occur in moderate numbers. A case study showed that frequent large, semi-infaunal *Turritella duplicata* occur on the high-energy Nopparat Thara tidal flat in Krabi, South Thailand. High-energy, marginally marine to tidal flat environments in the Kimmeridgian also contain moderate numbers of nerineoid gastropods. The recent siliciclastic and fossil carbonate tidal flat environments can be shown to have similar sediment properties and show a similar population of infaunal echinoids and gastropods as well as burrowing crustaceans. The semi-sessile, suspension-feeding, large, high-spined gastropods are believed to indicate environments of high food availability and relatively high water energy. As such they delimit topographical high-zones on the Jura carbonate platform and are an important paleoecological indicator. As the platform is located in a shallow epeiric sea, upwelling as a dominant food source is ruled out. Run-off and coastal erosion of emerged areas on the platform must be invoked as the primary sources of large quantities of suspended labile organic carbon. The studied mass accumulations of nerineoid gastropods occur in two stratigraphical intervals in the early Late Kimmeridgian and at the Kimmeridgian- Tithonian boundary. In both cases the mass accumulations overlie intervals of microbial laminites preserving dinosaur footprints and are topped by an iron-hydroxide-impregnated, eroded and karstified hardground. The hardground is overlain by an interval of alternating marl and limestone beds. These contain innumerable in situ and transported small oysters (*Nanogyra*) and are known as the "Virgula Marls". The recurrent conspicuous facies development from dinosaur tracks to nerineoid accumulations to hardgrounds to Virgula Marls are referred to as the Upper (UNVS) and Lower Virgula Nerineoid Succession (LNVS). The depositional history leading to their formation has been analysed in detail. Palaeoenvironmental information was gathered from a total of 17 closely spaced sections from two stratigraphic intervals. With this information the depositional history of the NVS could be reconstructed. Lateral facies variations indicate that the succession was produced on a series of tilting tectonic blocks. During times of emergence soil covers were formed on the blocks. These are indirectly evidenced by the karstified and impregnated hardgrounds. Vegetation could establish itself in these soils, which subsequently formed the food source for the dinosaurs on the platform. Subsequent pulses of relative sea level rise led to the erosion of these soils and vegetation alike and formed - Abstract wave-cut terraces. The organic material and the clays were flushed into the platform waters. Evidently they

were transported past the high-energy environments of the nerineoids as these are composed of pure carbonate sands. However, they were responsible for the perturbation and suffocation of the carbonate factory in adjacent local, tectonically induced depressions where both clays and plant remains were deposited. Both *Nanogyra* and nerineoid mass accumulations are thought to have been sustained by the labile organic carbon derived from the erosion of the platform.

**Noémie STIENNE (2010)**

**Paléoécologie et taphonomie comparative en milieux  
carbonates peu profonds (Oxfordien du Jura Suisse et  
Holocène du Berlize) (248 pp.)**



## Abstract

Sediment on tropical platforms stems from terrigenous sources and from authigenic carbonate production, and the accumulation is also influenced by lateral migration of sedimentary bodies. The qualitative and quantitative evolution of the sediment flow is controlled by allocyclic and autocyclic processes. The studies of Pittet (1996), Plunkett (1997), Dupraz (1999), Hug (2003), and Védérine (2007) describe the stratigraphic and sequential organization on the Swiss and French Jura platform during the Oxfordian. The sedimentary sequences are mainly related to orbital cycles, with periodicities of 20, 100, and 400kyr, which correspond respectively to the orbital precession and short and long eccentricity cycles. Thus, a well-defined sequence- and cyclostratigraphic timescale for the Middle to Late Oxfordian has been established and was synthesized by Strasser (2007). This gives a good framework to study the distribution of the facies and taphofacies within elementary depositional sequences, i.e. with a time resolution higher than 20 kyr. This intrasequential stratigraphic approach has been applied to the Vorbourg and Hautes-Roches sections, for the interval situated above sequence boundary Ox6 defined by Hardenbol et al. (1998) and around the inversion of the sea level trend corresponding to the Ox6+ sequence boundary (Hug 2003). During the selected interval, the Swiss Jura experienced a transition from a humid to a more arid climate, resulting in the decrease of meteoric alteration in the hinterland. Thus, the sediment discharge to the adjacent lagoons changed, and a transition from a mixed carbonate-siliciclastic sedimentary system to a carbonate-dominated one occurred. Eight palaeoecosystems are distinguished, based on microfacies and fossil assemblages, from a restricted coastal brackish environment to a reefal domain, and characterized in terms of salinity, hydrodynamics, oxygenation, trophic level, turbidity, granulometry, degree of substrate induration, and mineralogical matrix composition.

A better understanding of the Oxfordian sedimentary record was gained by a comparative study of the Ambergris Caye and Placencia areas on the Belize platform. The evolution of the Holocene sediments has been studied based on nineteen cores and is interpreted in relation with the flooding of the Pleistocene substrate. The cored sediments thus mainly belong to the highstand deposits. The analysis of surface sediment allows describing seven main ecosystems, from tidal flat to reefal lagoons. These ecosystems are characterized in terms of benthic guilds, salinity, hydrodynamics, oxygenation, trophic level, turbidity, granulometry, and degree of substrate induration. The matrix composition displays a strong contrast depending on the depositional environment of the Holocene sediments: the sedimentation in the northern Ambergris Caye area is carbonate-dominated, as opposed to the mixed carbonate-siliciclastic sedimentation of the southern area surrounding Placencia. This sedimentary contrast reflects the geomorphological and geological contrast of the hinterland: flat and carbonate-dominated in the north, and with high granitic and metamorphic relief in the south.

The taphonomic analysis of both study areas (Jura and Belize) is based on quaternary taphograms, obtained by using the statistical software R, comparable to the ternary taphograms of Kowalewski et al. (1995). Selected taphonomic features are: disarticulation, fragmentation, wearing, micritization, biogenic encrustation, and perforation. Four degrees of alteration, or taphonomic grades, are defined per feature. The taphogram axes represent these grades. The selected benthic organism groups are: gastropods, bivalves, foraminifera, Halimeda, corals, and echinoids.

The study of taphograms from Belize and the Swiss Jura reveal that taphofacies, or taphonomic signatures, are made by differential mixing of taphonomic grades per taphonomic feature. In other words, an assemblage displays bioclasts that can be characterized either by a dominant taphonomic grade, or by different taphonomic grades. The mixing depends on the factors that control the ecosystem. The main

discriminating factors are: the depth of the taphonomically active zone (TAZ; Davies et al. 1989), the residence time in the TAZ, the sedimentation rate, the mineralogical matrix composition, the diagenetic environment, the hydrodynamic regime, the granulometry, the presence of an indurated and/or stabilized substrate, the rate of benthic production, the faunal and floral benthic composition, the mineralogical and organic composition and the structure of skeletal components.

The intrasequential analysis can be done with a temporal resolution of only a few hundred to a few thousand years due to time-averaging (e.g., Flessa et al. 1993). However, even within intrasequential deposits (lowstand, transgressive, highstand), microfacies show evidences that the sedimentation rate is not constant. These evidences include signs of early cementation (indurated surfaces, nodulization), and of momentary perturbations in the taphonomic and sedimentologic signatures. The development of transgressive and maximum-flooding surfaces within the elementary sequences as well as of sequence boundaries also indicates variations of the sedimentation rate.

The sedimentation rates have an influence on the exposure time of bioclasts to the taphonomic processes. In Belize and in the Swiss Jura, low sedimentation rates are associated with a strong physical, chemical, and/or biological alteration, depending on the conditions of the depositional environment.

The oscillatory character of the rate of change of accommodation space, driven by the orbital cycles, leads to an alternation of stages with fast change of the rate of variation of accommodation (e.g., inflexion points on the sinusoidal curve) and stages with stabilization of the rates (e.g., points with minimal and maximal amplitudes on the sinusoid).

When the rates of variation of accommodation are stable, the ecosystem can adapt effectively to the environmental change. As a consequence, an equilibrated evolution is maintained between authigenic carbonate production and accommodation rate. Consequently, the taphofacies displays a mixing of taphonomic grades.

Three cases can be observed if the sedimentation and accommodation rates are not in equilibrium. Either, sedimentation rate exceeds accommodation: taphofacies are dominated by an intense physical alteration (late highstand deposits, lowstand deposits). Or, accommodation variation and/or accommodation space exceed sedimentation rate: the early transgressive deposits are characterized by a strong physical alteration, and the maximum-flooding intervals display a strong biological and chemical alteration. Finally, there are cases in which ecosystems, and therefore the associated benthic production, become stabilized in spite of high accommodation conditions (highstand deposits): the taphofacies corresponds to the mixing of taphonomic grades, showing a signature comparable to cases with sedimentation and accommodation rates in equilibrium.

The (tapho)facies organization within elementary depositional sequences does not necessarily have an iterative and predictable character because it depends on the conditions of evolution of each specific (palaeo)environment. Each analysis has to be based on a detailed knowledge of the studied (palaeo)ecosystems. Then, intrasequential analysis can identify the sedimentological interruptions, modifications, and transitions that occur with a timescale shorter than 20 kyr. These are expressed with variable intensity as a function of the location of the depositional environment on the platform, and of the degree of superposition of orbital cycles with different periodicities.

**Daniel MARTY (2008)**

**Sedimentology, taphonomy, and ichnology of Late Jurassic dinosaur tracks from the Jura carbonate platform (Chevez-Combe Ronde tracksite, NW Switzerland): insights into the tidal-flat palaeoenvironment and dinosaur diversity, locomotion, and palaeoecology (278 pp.)**



**Abstract**

Dinosaur tracks are biogenic, sedimentary structures and not body fossils or biological objects in the common sense. They result from the complex interaction of the kinematics of the trackmaker, its foot anatomy, and the substrate properties, and from taphonomic processes acting prior to the incorporation of the tracks into the sedimentary record. The objective of this work is an interdisciplinary study of a large sample of dinosaur tracks and trackways linking sedimentology with vertebrate ichnology, palaeontology, and palaeoecology.

Excellent conditions are provided by the Late Jurassic (Kimmeridgian) Chevez—Combe Ronde tracksite, which is one of several tracksites located on the future course of the Transjurane highway near Porrentruy (Canton Jura, NW Switzerland). Here, eight superimposed dinosaur track-bearing surfaces were systematically excavated level-by-level within a 0,65 m thick laminite interval, unearthing almost 1400 dinosaur tracks. The main track level, located at the base of the interval, is the most diverse ichnoassemblage composed of 14 trackways of tiny (Pes Length < 25 cm) and small (25 cm < PL < 50 cm) sauropods and 43 trackways of minute (PL < 10 cm), small (10 cm < PL < 20 cm), and medium-sized (20 cm < PL < 30 cm) bipedal, tridactyl dinosaurs.

The main issues are: (1) identification of true tracks, undertracks, and overtracks, and their relationships with substrate properties, their link with the exposure index, and their utility in the reconstruction of the palaeoenvironment; (2) implications of the main track level ichnoassemblage for dinosaur behaviour, the terrestrial palaeoecosystem, and vertebrate ichnofacies; (3) relationships between variability in trackway patterns and configurations with locomotion speed, behaviour, and substrate properties as well as implications for locomotion capabilities; (4) Quantification and relevance of sauropod trackway gauge; and (5) interpretation of manus-dominated and pes-only sauropod trackways.

The approach is first actualistic by studying human footprints and processes acting during their formation and preservation on modern tidal-flats. In these highly structured environments, microbial mats are ubiquitous, strongly facies-specific, and occupy a key position during and after footprint formation. Undertracks readily form in biolaminated sediment, whilst underprints and deep tracks are common in unlaminated, water-saturated sediment. Most consolidated vertebrate tracks are affected by taphonomic processes, including renewed and/or repeated growth of microbial mats leading to the formation of modified true tracks, internal overtracks (track fills), and overtracks.

The sauropod tracks and the encasing laminite interval of the Combe Ronde site are then subject of detailed sedimentological and taphonomical analyses. This discloses the sediment properties at the time of track formation and reveals the processes modifying the tracks during subaerial exposure and integrating them into the sedimentary record. Track morphology, associated track features, and sedimentary features can be linked with the exposure index, identifying the palaeoenvironment as a supratidal flat not located in close proximity to a coastline. These flats were susceptible for track recording only during short periods after wetting due to a rainy period or due to occasional storms. Longer periods of subaerial exposure prior to burial are indicated by the presence of internal overtracks and/or overtracks, and rapid covering up is

indicated by the lack of overtracks on top of tracks with large displacement rims. Cross-sections of sauropod tracks provide insight into the consolidation history of the substrate prior to track formation and into the walking dynamics of dinosaurs, confirming that sauropods put their hindfeet in a pronounced plantigrade way on the ground.

The level-by-level superimposition of the studied surfaces enables to identify true tracks, undertracks, and overtracks. The best-defined true tracks (anatomical morphotypes) of the main track level are then used for ichnotaxonomy and trackmaker identification, and the detailed analyses of trackway parameters, including trackway gauge, provide insight into the locomotion capabilities of dinosaurs.

The best-defined minute and small tridactyl tracks can be assigned to the ichnogenus *Carmelopodus*, extending it from the Middle Jurassic into the Late Jurassic. These tracks were likely left by a small theropod dinosaur similar in size to *Compsognathus* or *Juravenator*. The medium-sized tridactyl tracks of morphotype II exhibit some of the typical features of the ichnogenus *Therangospodus* (attributed to large and robust theropods) but also some of ornithopod ichnotaxa.

The sauropod trackways show a wide range of patterns and configurations but are all medium- to wide-gauge. Therefore, they are assigned tentatively to the ichnogenus *Brontopodus* attributed to derived “brachiosaurid” or “titanosaurid” dinosaurs. The variability of the trackways reflects the general locomotion capabilities of the trackmakers and is an expression of individual walking style and behaviour, which may be related to substrate properties. Trackway patterns (the degree of manus overprinting by the pes) and different trackway configurations including trackway gauge are not only related to locomotion speed, and they provide no evidence of a relationship with ontogeny.

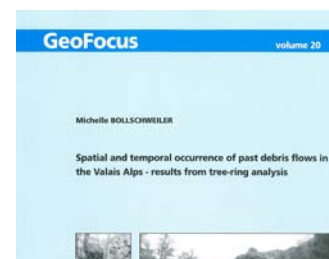
The gauge of sauropod trackways can be quantified with the pes trackway ratio and the here defined [WAP/PL]-ratio (Width of the pes Angulation Pattern / Pes Length). Gauge is possibly related to the substrate and the behaviour of the trackmaker adapting to it, but this does not change the overall medium-gauge to wide-gauge appearance of the trackways. The manus-dominated and pes-only sauropod trackways of the Combe Ronde site are explained by trackmakers exerting more pressure on the manus than the pes, and by overprinting of the manus by the pes, respectively.

The alignment of trackways on the main track level shows no evidence of a nearby shoreline and of interactions between the different groups of dinosaurs. It indicates gregarious behaviour amongst tiny and small sauropods, and suggests that minute and small bipedal dinosaurs were frequent visitors on the supratidal flats.

The ichnoassemblage of the main track level is the first one found in the Jura Mountains displaying abundant minute and small tridactyl tracks. This is also typical for the other Ajoie ichnoassemblages, which further exhibit tracks of tiny to large (up to 1,1 m PL) sauropods, and tracks of medium-sized to large (up to 0,8 m PL) bipedal dinosaurs. Sauropod trackways include narrow-gauge and wide-gauge trackways indicating the presence of “basal” and derived sauropods. This suggests that dwarfed insular animals can be excluded as trackmakers of the tiny and small sauropod trackways of the Ajoie ichnoassemblages and the Combe Ronde tracksite and that the Jura carbonate platform was connected with the landmasses of the London-Brabant Massif and the Massif Central during periods of emersion. Dinosaurs used the Jura carbonate platform for the establishment of *in situ*, predominantly saurischian dinosaur populations, but also as a migration corridor between the massifs.

Because the Ajoie ichnoassemblages are dominated by small tridactyl tracks, they differ from other Jurassic tetrapod ichnofacies in carbonate settings, notably from the *Brontopodus* ichnofacies. In the case of those ichnoassemblages commonly attributed to the *Brontopodus* ichnofacies, the lack or rareness of small tridactyl tracks may indicate the absence of small trackmakers in those palaeoenvironments or unsuitable conditions for the formation and preservation of small tracks.

This study highlights the benefits of systematic and interdisciplinary analyses of dinosaur tracks, which disclose variations related to behaviour and to differences in substrate. This allows recognizing anatomical morphotypes and trackway configurations representative of typical trackmaker behaviour. The latter can then also be used in ichnotaxonomical classification. Similar approaches should be in the focus of future work and performed on the other tracksites and ichnoassemblages of the Ajoie. Together with the evidence from other tracksites of the Jura Mountains, this will contribute towards a better understanding of the terrestrial palaeoenvironments and palaeogeography, and of dinosaur palaeoecology and palaeobiogeography on the Jura carbonate platform.



Michelle BOLLSCHWEILER (2007)

**Spatial and temporal occurrence of past debris flows in the  
Valais Alps – results from tree-ring analysis (182 pp.)**

**Abstract**

Debris flows are common mass-movement processes in most mountainous regions of the world, where their unpredictable and sudden occurrence represents a major threat to transportation corridors and settlements. Increased anthropogenic activity in regions exposed to debris-flow risk renders a detailed hazard assessment inevitable. However, archival data on past events remains scarce and, most of the time, fragmentary. Similarly, tree-ring analyses have been used only exceptionally to investigate past debris-flow activity. It is therefore the aim of this PhD thesis to reconstruct debris-flow frequencies for different torrents within the Valais Alps (Switzerland) using dendroecological methods in order to (i) contribute to the systematic acquisition of data on past events for hazard assessments, and (ii) to reconstruct the spatial extent and behavior of previous events. Also, the extension of tangential rows of resin ducts (TRD) was assessed in trees injured by debris-flow activity in order to improve knowledge regarding growth reactions of impacted trees.

In the first paper, 28 injuries from 8 European larches (*Larix decidua* Mill.) wounded during debris-flow activity in the Feergraben (Simplon region, Valais Alps) were investigated. The aim of the study was to assess the onset of TRD after wounding, as well as their vertical and tangential extensions. Consequently, 182 stem discs were prepared for analysis. This study represents the first fundamental research on the vertical and tangential extension of TRD in trees that have been impacted by a geomorphic process under natural conditions. As the trees were injured in October 2000 and November 2004, i.e. after the end of the local growing season, TRD could only be observed in the earlywood cell layers of the new growth ring. The vertical extension of TRD averaged 74 cm, but was much greater above rather than below the injury. At the height of the wound, TRD were present in 18% of the circumference remaining vital after the impact. In addition, a certain delay in the onset of the reaction could be observed with distance from the centre of the impact. Therefore, increment cores should be sampled close to the wound in future studies in order to avoid dating mistakes.

For the reconstruction of past debris-flow events in two catchments located in Val Ferret (Valais Alps, Switzerland), a total of 556 increment cores from 278 heavily affected European larches, Norway spruces (*Picea abies* (L.) Karst.) and Scots pines (*Pinus sylvestris* L.) were sampled from the cones of Reuse de Saleinaz and Torrent de la Fouly. Tree-ring analyses allowed reconstruction of 39 events for the period 1743 to 2003 at Reuse de Saleinaz. Along the debris-flow channel of the Torrent de la Fouly, 30 events were reconstructed for between 1862 and 2003. Although the catchments and channels of the two torrents evince considerable differences in geology and morphology, debris-flow frequencies are very similar with, on average, one event every eight years for the period reconstructed. In both catchments, material is apparently readily available and the triggering and occurrence of events thus seems to be transport- rather than weathering-limited.

The aim of the third study was to assess spatio-temporal patterns of past debris-flow activity on the cone of the Bruchji torrent (Blatten b. Naters, Valais). Based on a detailed geomorphic map (scale 1:1000), 401 obviously disturbed European larches and Norway spruces were sampled. In total, 960 growth disturbances identified in the samples allowed assessment of 40 event years for the period 1867-2005. The combination of tree-ring analysis with geomorphic mapping allowed identification of eleven previously active debris-

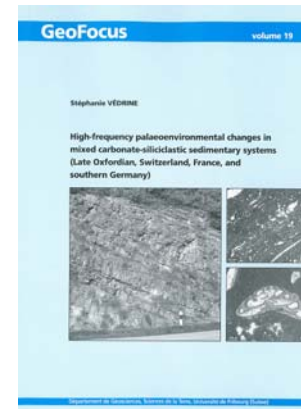
flow channels. In addition, five patterns of spatial behavior of past events could be assessed. While older events preferentially affect trees in the western part of the cone, the flow regime apparently changed during the mid-1930s towards the eastern part of the cone.

In the last part of the study, two different dendroecological approaches were combined for the assessment of past debris-flow activity. Classical dating of growth disturbances with dendrogeomorphological methods allowed reconstruction of 49 events between AD 1782 and 2005. The spatial extent of events was determined by a positioning of disturbed trees on the geomorphic map. For sectors where survivor trees were absent, the oldest post-event trees were sampled and their age assessed counting the number of growth rings. Tree rings were added when the pith was absent on the increment core and to account for missing rings at sampling height. As a result, we were able to approximate the real age of trees with reasonable accuracy. The coupling of two different dendroecological approaches – dendro-geomorphological event reconstruction and assessment of germination dates of successor trees – allowed estimation of the minimum time elapsed since the last debris-flow activity for 23 of 29 channels on the cone. The time elapsed since the last event seems to increase with distance from the current channel.

In conclusion, this PhD thesis provides new insights into the possibilities and limitations of tree-ring analyses in debris-flow research. The onset, as well as the tangential and vertical extension of TRD, could, for the first time, be assessed in trees impacted by debris flows. In addition, frequencies of past events could be reconstructed for four torrents in the Valais Alps. 10-year frequencies indicate times of high torrential activity in the past, especially during the warm-wet period between 1916 and 1925. In contrast, a decrease in the number of events can be observed since 1996. However, it needs to be said that a part of this decrease in frequency should be considered as being the result of anthropogenic interventions in the channels, rather than the effect of changing climatic conditions. While this thesis provides valuable data for hazard assessment, reliable data on the magnitude of past events remains scarce. Consequently, further research needs to determine not only changes in the frequency, but also the influence of a changing climate on the magnitude of future events.

Stéphanie VEDRINE (2007)

**High-frequency palaeoenvironmental changes in mixed carbonate-siliciclastic sedimentary systems (Late Oxfordian, Switzerland, France, and southern Germany) (216 pp.)**



**Abstract**

The main goal of this study is to monitor the high-frequency palaeoenvironmental changes occurring during a marine transgression in mixed carbonate-siliciclastic sedimentary systems. Based on a well-established bio- and sequence-stratigraphic framework, a narrow time window in the Bimammatum Zone of the Late Oxfordian is investigated. Seven shallow platform sections (Swiss Jura, Lorraine), two deep platform sections (Haute-Marne, Swabian Jura), and one basin section (SE France) have been logged and analysed in detail. Then, the deposits have been interpreted in terms of palaeoenvironments and sequence- and cyclostratigraphy with a high time resolution. Facies and microfacies analysis allows to propose depositional models for the Swiss Jura platform and the other studied areas. The high-resolution sequence- and cyclostratigraphic analysis permits defining hierarchically stacked depositional sequences: medium-scale, small-scale, and elementary sequences, formed through orbitally controlled sea-level changes with periodicities of 400, 100, and 20 kyr, respectively.

This study investigates deposits comprised in the first half of a medium-scale sequence, corresponding to two small-scale sequences, each composed of five elementary sequences. In the shallow platform sections, an elementary sequence generally consists of one to four beds including more or less developed marl intervals. In the deep platform sections, an elementary sequence generally consists of one or two limestone beds with a more or less developed marl interval. In the basin section, an elementary sequence is defined by one marl-limestone couplet.

The good correlation of depositional sequences over long distances between the seven shallow platform sections and the similar number of elementary sequences in all sections are valuable arguments that allocyclic processes must have been involved in the formation of these depositional sequences. Additional factors such as the position on the platform and the pre-existing morphology have to be considered in the formation of depositional sequences on a shallow platform. The presence of thickness variations at the scale of small-scale and elementary sequences reveals variable sediment accumulation rates, interpreted as resulting mainly from differential subsidence due to the activity of tectonic blocks. The relief created by tectonics therefore contributed significantly to the general facies distribution. Furthermore, the irregular distribution of siliciclastics can be explained by localized depressions, which were created by differential subsidence and served as depocenters.

The vertical and lateral distribution of facies, oncoids, and benthic foraminifera is investigated within the narrow high-resolution time framework established (20-kyr time resolution). Significant lateral facies changes are evidenced by comparison of time-equivalent small-scale and elementary sequences between the Swiss Jura sections. They reflect the dynamics and complexity of sedimentary systems where juxtaposed sub-environments evolved and shifted through space and time.

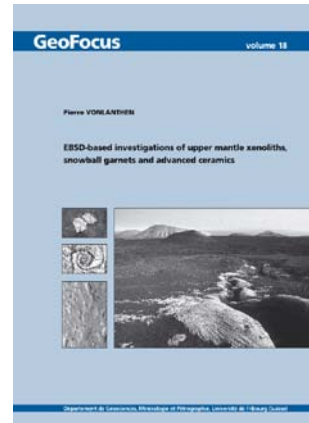
Four types of oncoids are defined based on surface morphology, configuration and composition of the cortex, and the encasing sediment. Micrite-dominated oncoids (types 1 and 2) have a smooth surface and *Bacinnella-Lithocodium* oncoids (types 3 and 4) display a lobate surface. The stratigraphic and spatial distribution of these oncoid types shows a correlation with the sequence-stratigraphic evolution, and thus with relative sea-level fluctuations. At the scale of 100-kyr and 20-kyr sequences, type 1 and 2 oncoids are preferentially found around sequence boundaries and in transgressive deposits, while type 3 and 4 oncoids are preferentially found around maximum floodings and in highstand deposits. This implies that changes of

water energy and water depth were direct controlling factors. Discrepancies in oncoïd distribution point to additional controlling factors. Platform morphology defines the distribution and type of the lagoon where the oncoïds flourished. A low accumulation rate is required for oncoïd growth. Additionally, humidity changes in the hinterland act on the terrigenous influx, which modifies water transparency and trophic level and thus plays a role in the biotic composition and diversity in the oncoïd cortex. This study demonstrates that oncoïds are valuable proxies for high-resolution palaeoenvironmental and palaeoecological studies.

The benthic foraminifer assemblages of the Swiss Jura sections include agglutinated forms (Textularids), in a lower amount porcelaneous forms (Miliolids), and locally hyaline foraminifera (only Lenticulina). The distribution of porcelaneous and hyaline foraminifera shows a correlation with the sequence-stratigraphic evolution. Miliolids are preferentially found in the highstand deposits of the elementary and/or small-scale sequences. The hyaline foraminifera, rare in the studied sections, are preferentially found in the transgressive deposits of elementary sequences. Consequently, the benthic foraminifera are indirectly linked to relative sea-level (accommodation changes) and indirectly to climate changes (sediment and nutrient input).

The distribution of the benthic foraminifer *Mohlerina basiliensis* and *Bacinella-Lithocodium* oncoïds shows a strong correlation. The co-occurrence of these two components suggests that they require similar ecological conditions. In addition, the successively later occurrence of *M. basiliensis* from “distal” to “proximal” sections illustrates the stepwise flooding of the platform and thus implies a dependence on normal-marine conditions.

Clay-mineral assemblages and stable isotopes give palaeoenvironmental information on the scale of 400 kyr and 100 kyr but a higher time resolution is difficult to obtain probably due to time averaging by sedimentological and/or diagenetic processes. The medium-scale trends of the kaolinite content and K/I ratio between all sections from shallow platform to basin show a correlation, particularly around the medium-scale SB Ox6+ and MF Ox6+. Clay mineral distribution was not only controlled by climate changes but also by relative sea-level changes and platform morphology. Carbon and oxygen isotope analysis shows minor fluctuations ( $\pm 1\%$ ) that probably reflect variations of local environmental conditions (e.g., salinity, temperature, trophic level).



**Pierre VONLANTHEN (2007)**

**EBSD-based investigations of upper mantle xenoliths,  
snowball garnets and advanced ceramics (114 pp.)**

**Abstract**

Since the beginning of the nineties, the automation of electron backscatter diffraction (EBSD) has completely revolutionized texture analysis carried out on rocks and man-made materials. Among the most striking advances, not only does EBSD allow a relatively rapid and straightforward bulk texture analysis, but it also allows the grain-by-grain determination of crystallographic orientations. The interest for the technique is obvious for academic purposes but also for the industry, as most of the physical properties of materials depend on the lattice preferred orientation (LPO) of the constituting grains. Since EBSD is the main investigation method applied in each of the three investigated case studies, it is clearly the keystone of the present work.

In the first Case Study, a petrophysical analysis of twelve upper mantle peridotite xenoliths collected in the Quaternary basalt fields of Lanzarote (Canary Islands) is presented. The goal of this project is to determine the deformation mechanisms responsible for the formation of observed textures and to calculate the propagation velocities of seismic waves through the samples. Seismic velocities are of particular interest as two contradictory interpretations resulting from the same campaign of field geophysical measurements are reported in the literature. The present EBSD analysis is aimed at providing new data on the seismic properties of the upper mantle in this region, in order to either confirm or reject the interpretations inferred from field geophysical measurements. For each sample, the LPO of olivine, orthopyroxene and clinopyroxene was measured. Two deformation mechanisms, probably dominated by simple shear under low strain rate and relatively high temperature, are put forward. The velocities of P-waves calculated from the LPO and the elastic constants of the minerals for upper mantle pressure and temperature conditions confirm the most recent geophysical interpretation. In addition, this project also highlights remarkable examples of anomalous foliation, characterized by an orientation of the foliation plane at right angle with respect to the olivine [100] pole maximum. Based on microstructural, crystallographic and geochemical arguments, the anomalous foliation is interpreted as a result of strong recovery processes.

The second Case Study is devoted to the formation of snowball garnets from the Liassic Stgir series (Lukmanier Pass, Switzerland). For more than two decades, the mechanisms responsible for the formation of snowball garnets have been in the center of an intense debate. Based on a multi-analytical approach involving micro-computed X-ray tomography, electron microprobe and EBSD analyses, two successive growth mechanisms are put forward for the formation of the analyzed garnets: whereas several pieces of evidence seem to indicate that the first stages of growth are initiated in a rotational context, the final stages of growth occur in a post-kinematic regime. This assumption is based on (1) the occurrence and distribution of secondary Mn maxima inside the spiral, (2) the constant crystallographic orientation of the bridges connecting the core and the arms of the spiral and (3) the post-kinematic growth of garnet by replacement of deformed mica-rich levels. In addition, EBSD brings into light the fact that snowball garnets from the Lukmanier Pass are not made of a unique grain with a single crystallographic orientation but of several grains with different, distinct orientations.

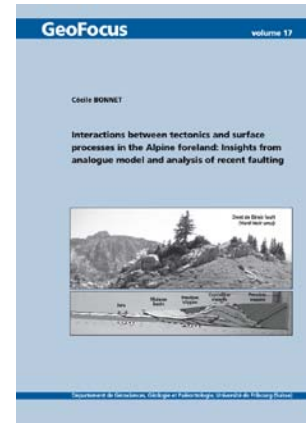
In the third Case Study, the distributions of coincidence site lattice (CSL) grain boundaries in alumina and zirconia ceramics are investigated through EBSD. The main interest of this project lies in the fact that most physical properties involved in the processing and behavior of ceramics depend on the nature and distribution of grain boundaries. 2D spatial models consisting of 50000 randomly oriented grains have been simulated to serve as references for random distributions. Comparison between the simulated and measured

distributions has shown higher CSL grain boundary fractions in the latter. This trend is particularly obvious for the samples sintered at high temperature. In alumina, change in individual CSL grain boundary fractions with temperature is crystallographically controlled and directly dependent on the orientation of the misorientation axis with respect to the [0001] axis. Finally, based on the data of zirconia, this study has also allowed the definition of a so-called general prominence factor likely to be used as a simple criterion to determine the randomness of the CSL grain boundary distribution in FCC-type materials.

This PhD thesis has attempted to show the central role played by EBSD in earth and materials sciences. The various types of materials analyzed as well as the multidisciplinary character of the different case studies give evidence for the polyvalence of the method.

**Cécile BONNET (2007)**

**Interactions between tectonics and surface processes in the Alpine foreland: Insights from analogue model and analysis of recent faulting (189 pp.)**



**Abstract**

To study the dynamics of an orogen-foreland system and more particularly the impact of surface processes on its development, we base our work on two main axes. In a first part, using analogue tapered wedge models, we investigate the interplay between tectonics, erosion and sedimentation during the orogenic growth. The basis model mimics the evolution of a wedge section extending from the orogen to its foreland basin, with both the structural and the lithological heritages simulated. In a second part, the focus is on the recent tectonic and geomorphologic processes affecting the Swiss Prealpes klippen belt and surrounding structural units (Molasse Basin and Jura fold-and-thrust belt). Remote sensing analyses allow to evaluate the impact of tectonics on the drainage pattern and landscape morphology. In addition, local field investigations in the Prealpes provide information on the nature and kinematic of brittle fractures and the paleostress fields.

**Insights from analogue modeling**

The series of seventeen analogue model experiments is based on a section across the north-western Alpine wedge and foreland basin. This type of analogue model obeys to the dynamics of a tapered wedge and the structures produced are determined by the wedge mechanics. The orogen grows by incremental step of shortening, while outside processes such as erosion and sedimentation may influence the criticality of the taper. This is the case in the last six experiments, where erosion and sedimentation are manually performed in varying rates. These experiments are studied in detail and allowed to investigate and quantify: sediment budget, dynamics and timing of development of the orogen and adjacent foreland basin, uplift paths of particles, etc

The experiments show that two main mechanisms control the orogenic growth: frontal accretion and underplating. In the foreland basin, frontal accretion leads to the development of a foreland thrust belt, while in the hinterland, simple underthrusting and subsequent underplating lead to the formation of an antiformal nappe stack. The foreland basin evolution is mainly towards the front of the orogenic wedge but it differs depending on the amounts of erosion/sedimentation. Its evolution and internal structuring are governed by the wedge mechanics, thought to be the main controlling mechanism in a feedback interaction with surface processes. The basin grows to a threshold width and remains more or less constant during the subsequent evolution. This is possible because some older formed fold-and-thrust units are being eroded out of the record in the trailing part of the basin, while new units grow in its frontal part. During the development of the foreland fold-and-thrust belt, we observe the erosion of entire thrust units of freshly sedimented materials. As these types of events are untraceable in the tectonic and sedimentary record, this process leads to underestimating total shortening obtained from balancing remaining units only.

Our analogue models show the importance of feedback mechanisms of erosion/deposition on the wedge mechanics and the punctuated thrust development, as well as the cyclic behavior of surface processes. The variations in rates of erosion and sedimentation strongly modify the extent, the morphology, and the structure of the constitutive units. The timing of development and the material paths also differ depending on the rates of surface processes in the different models. It appears for instance that particles located in the converging lower plate or in the upper plate show very complex uplift paths related to the different tectonic stages.

The correlation between models and Alpine tectonic cross-sections emphasises the role of erosion and

sedimentation on the dynamics and development of the orogen and adjacent Molasse Basin. Along strike changes in the geometry of the orogen can be explained by differences in surface processes. In addition, the main stages in evolution of the foreland basin and hinterland observed on the analogue models can be correlated in time and space with the major tectono-sedimentary events of the Alpine belt. These stages of evolution are for instance corroborated by the nature of pebbles in the Alpine domain which coincide with the Alpine orogenic evolution and timing. Finally, we suggest that flexural basin evolution mechanisms are secondary in the case of the Swiss Alpine Molasse Basin and that the first order basin evolution is governed by the internal mechanics of a tapered wedge type model.

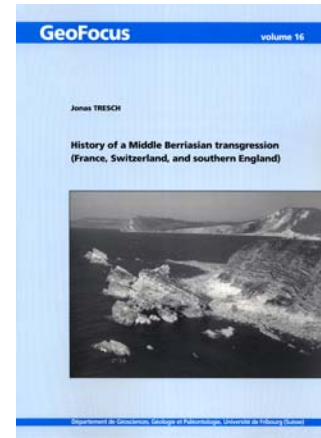
### **Insights from morphostructural study and stress analysis in the Prealpes**

The Prealpes klippen are constituted by a series of allochthonous tectonic klippen located along the northern front of the Swiss and French Alps. Their emplacement onto the Alpine foreland took place in the Early Oligocene (30 Ma). The fracture pattern in the klippen is complex since it is the final result of fold-and-thrust activity, neotectonics and certainly recent tectonics (post-nappe emplacement). To investigate the nature and kinematics of observed fractures in the Prealpes, we performed several types of analyses.

We first used remote sensing to determine the orientations of analysed structures. A morphological study of the area located between the klippen and the Molasse Plateau suggests that the hydrographic network mainly follows both glacial and structural trends. We then analysed locally the fracture and lineament orientations in three study areas located in the Swiss Chablais and in the Western Prealpes Romandes. Among different deformational models applicable to fault systems, the Riedel shear system appears to explain best the variety of obtained fault directions.

In the same three study areas, we investigated in the field the movement on fault planes in order to obtain paleostress orientations. The following chronology is suggested to explain the different deformational structures observed in the Chablais and Western Romandes Prealpes: initial layer parallel shortening, is followed by folding and thrusting with synfolding axial parallel extension generating extensional veins perpendicular to fold axis. Post-folding, local strike-slip components of faults may be observed as well as strike-slip movement reorienting the previously formed vein sets. Finally, during the last stage of deformation, large-scale faults develop, cross-cutting the existing fold-and-thrust structures.

To interpret the local stress fields, while integrating the results from the different datasets, we propose a more regional deformational model that extends from the Prealpes, through the Molasse Plateau to the Jura. The local Riedel shear zones may be combined in a general transcurrent model for the Alpine foreland. In addition, we suggest that the bulk of the brittle deformation in this transcurrent regime is recent and possibly has developed in a tectonic regime coincident with the present day stress field.



**Jonas TRESCH (2007)**

**History of a Middle Berriasian transgression (France, Switzerland, and southern England) (271 pp.)**

### **Abstract**

The aim of this study is to correlate and interpret transgressive deposits of three different depositional regions with high resolution: the marginal-marine carbonates of the Jura platform (France and Switzerland) and the Dorset region (UK). Additionally, a hemipelagic section of the Vocontian basin (France) has been integrated into the high-resolution correlation scheme. The Middle Berriasian transgression has been chosen because, in combination with subsidence, transgressive intervals create accommodation space, which can be filled with sediments. The best chance to preserve sediments and to obtain a relatively complete sedimentary succession is during increasing accommodation space. The Middle Berriasian transgression lies between the 3rd-order sequence boundaries Be4 and Be5 according to the sequence and chronostratigraphic chart of Hardenbol et al. (1998). The chosen sections are already well described and dated in the literature. In this study, all sections have been sampled on a decimetric scale in order to document their facies evolution in great detail. The observed facies zones have been integrated in two different facies models representing the palaeoenvironments of the Jura platform and the Dorset region. The facies and accommodation changes detected in each section are related to relative sea-level fluctuations and interpreted in terms of sequence stratigraphy (elementary, small-scale, and medium-scale sequences).

Most of the sections of the French and Swiss Jura platform have already been interpreted in terms of high-resolution sequence stratigraphy on the level of small-scale sequences (Wahry 1989, Pasquier 1995, Hillgärtner 1999). The lower part of the sections (Goldberg Formation and base of the Pierre Châtel Formation) has been dated by ammonites (Clavel et al. 1986) and with the help of charophyte-ostracode assemblages (Mojon 2002) and the upper part by benthic foraminifera (upper Pierre Châtel Formation and Vions Formation; e.g., Clavel et al. 1986). A remarkable environmental change from inter- and supratidal (Goldberg Formation) to shallow marine deposits (Pierre Châtel Formation) on the Jura platform represents the Middle Berriasian transgression.

Both investigated sections of the Dorset region are described bed-by-bed in the literature (Ensom 1985, Clements 1993). The upper part of the Lulworth Formation and the lower part of the Durlston Formation of the Durlston Bay and Worbarrow Tout sections have been re-logged on a decimetric scale and interpreted in terms of high-resolution sequence stratigraphy on the level of small-scale to elementary sequences. The rock succession implies a transgression from brackish-lagoonal to more marine environments. Marine conditions are indicated by the oyster banks of the Cinder Member, which corresponds to the Middle Berriasian transgression. The Durlston Bay section has been dated by magnetostratigraphy (Ogg et al. 1991, 1994) and charophyte-ostracode assemblages (Mojon 2002). A high-resolution sequence-stratigraphical interpretation of the Dorset sections on the level of elementary and small-scale sequences is presented in this study for the first time.

The Montclus section of the Vocontian basin is well dated by ammonites and calpionellids and has been interpreted in terms of sequence- and cyclostratigraphy (Pasquier 1995, Hillgärtner 1999). The transgression in the basin is marked by a change from relatively thick, irregular limestone beds to thinner and more homogeneous limestone-marl alternations. A high-resolution sequence-stratigraphical correlation of the Montclus section with sections of the Jura platform has been published by Strasser et al. (2004). The magnetostratigraphy established for the type-section of the Berriasian stage in Berrias (France) by Galbrun

(1985) and Galbrun et al. (1986) can be correlated to the Montclus section due to the sequence-stratigraphical interpretation of the Berrias section by Strohmenger & Strasser (1993).

A high-resolution correlation of several sections between the 3rd-order sequence boundaries has been worked out. This correlation framework fits well the biostratigraphic and magnetostratigraphic schemes published in the literature. The assumption that the base of the Pierre Châtel Formation on the Jura platform corresponds to the base of the Durlston Formation in Dorset (Cinder Member), discussed over decades in the literature, can be confirmed in this study.

According to Hardenbol et al. (1998), the time span between the 3rd-order sequence boundaries Be4 and Be5 is about 1.7 million years. Eighteen to twenty small-scale sequences have been identified within this interval. Based on this time span and the investigated stacking pattern of the sections, it is assumed that the deposition of the small-scale sequences has been controlled by relative sea-level fluctuations in tune with 100-ka orbital eccentricity cycles.

For an even higher time resolution, eleven sections of the Jura platform and the two Dorset sections have been selected to examine the sedimentary record of the four small-scale sequences around the large-scale transgression. Several well-preserved small-scale sequences are composed of five elementary sequences. Therefore, it is assumed that elementary sequences represent orbital precession cycles (20 ka).

The interpretation of the subtle palaeoenvironmental changes within the small-scale sequences is more complex. Some elementary sequences can be correlated between the sections and are considered to be controlled by relative sea-level changes (extrinsic factors). Others, however, cannot (or only partly) be interpreted in terms of sequence stratigraphy because intrinsic (autocyclic) processes dominated their deposition. However, autocyclic intervals can at least be delimited at the base and top by sequence-stratigraphical correlations.

Despite of the uncertainties in the correlation of elementary sequences, such high-resolution sequence-stratigraphical interpretations give the opportunity to reconstruct high-frequency palaeoenvironmental changes in different depositional realms with a time resolution of a few ten thousand years. The high-resolution sequence- and cyclostratigraphic correlation permits to monitor in detail the flooding of the Jura platform and the Dorset region. It can be shown that the transgression on the Jura platform is strongly diachronous mainly because of an important platform morphology and differential subsidence. Rapid facies changes occur in marginal-marine environments mainly due to threshold effects (e.g., flooding of morphological highs).

It is well known that a climate change from an arid, Mediterranean climate to more humid conditions took place during the Berriasian in NW and Central Europe (e.g., Deconinck 1987, Hallam et al. 1991, Allen 1998, Abbink et al. 2001). The high-resolution sequence- and cyclostratigraphical interpretation of this study enables us to analyze this climate change in more detail. It is assumed that oceanographic changes mainly related to the influence of cold Boreal and warm Tethyan surface waters were responsible for the climate change in these parts of Europe. A key role in the exchange of these water masses played the evolution of the Greenland-Norwegian Seaway during the Berriasian. Additional factors like the further widening of the proto-North Atlantic and the opening and closing of seaways between the epicontinental basins of Europe contributed to the climate change in the investigated regions. Climate changes on the Milankovitch-frequency band (orbital cycles) may have been controlled by variations in the extension of the atmospheric circulation cells and their palaeogeographic positions.

**Joëlle GOYETTE-PERNOT (2006)**

**L'Ambroisie: Analyse Statistique et Modélisation Numérique de sa Trajectoire Aérobiologique (274 pp.)**



**Abstract**

Allergic rhinitis as well as associated costs are constantly increasing, affecting a proportion always larger of the population across the world.

Ragweed is a source of pollen well known for its high allergenic properties. Characterized by heavy emissions of the pollen in the air from August to October of each year, its allergenic potential is greatly enhanced. This study deals with the problems induced by ragweed pollen and more specifically with the means currently available to understand the pollen cloud evolution during the pollination season. In addition to the analysis of the pollen cloud, another approach that could be developed to achieve in the future better pollination risk forecasts is presented. While travelling in the air, the pollen is directly influenced by the atmospheric conditions. The focus will be on the interplay of the meteorological parameters over the sampled pollen concentrations. This research under the theme of aerobiology, concentrates on the greater Montreal area which experiences each year serious cases of pollinosis related to ragweed (or “herbe à poux”, as it is locally referred to). Coming from North America, it has long been endemic, which makes the region an attractive research laboratory.

A review of the available literature is proposed first, in order to present an overview of the questions of rhythms and characteristics that make ragweed a high risk plant, responsible for more than 10% of the declared local allergic rhinitis. The aerobiological pathway of the pollen is then analyzed as well as the meteorological parameters that interfere at various degrees during each step of its transport in the atmosphere. Most of the effects occur in the lowest levels of the atmosphere where the turbulence is especially determinant of the pollen concentrations. In order to study these behaviours a number of measurements techniques and evaluation tools have already been tested and published. They are described and two complementary approaches are proposed in the following.

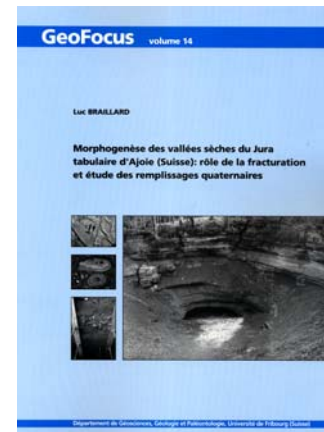
Among them, a statistical analysis of the pollen cloud behaviour over the period 1994-2003, is presented based on observed data. This decade is characterized by specially pollinic years from 1998 to 2001, associated with above-normal dry and hot springs and summers. A global analysis of pollinic risk according to weather types experimented in Montreal helps to identify more or less risky meteorological conjunctions taking into account frequency of occurrence and contribution to the global seasonal pollen load. It appears that the most frequent are also the larger contributors, what does not mean that one can neglect other situation, because even if they are less frequent, they are not necessarily less intense. Although the clinical threshold is high during all the seasons studied, the situation remains globally critical in Montreal.

If in situ observation as well as statistical analysis offer a consistent and interesting picture of potential pollinic risks over a region, more detailed analysis with the help of advanced numerical tools integrating fundamental principals of atmospheric physics, namely regional climate models, may offer the opportunity to analyse with very high spatio-temporal resolution, the simulated pollen cloud behaviour that should be as close as possible to the real one. This approach is innovative and presents a significant potential for the future. The multiple self-nesting methods that are used to simulate the behaviour of the ragweed pollen cloud over a grid centred above Montreal, includes 60X60 computation nodes with a 1 km spacing and 25 levels in the vertical. Results are saved every 15 min. That confers the enormous advantage of being able to study the spatio-temporal evolution of the cloud with a precision till now unavailable from field measurements as well as from available sampling techniques. The aerobiological pathway is reproduced in

full, from the emission to the pollen deposition including transport and dispersion. Emission is prescribed according to an available localisation source map and takes into account parameters obtained from the literature for the determination of fluxes. Once the pollen is embedded within the air flow, it is subjected to the thermo-dynamical evolution of the boundary layer. Typical end of summer conditions are simulated and analysed. Globally the simulation behaves like the observed tendencies. It allows to emphasize inter alia that small fluctuations of atmospheric conditions may affect significantly the development of the pollen cloud and by the same occasion, the areas affected by more or less important levels of risk. Results are encouraging and open a new field of research for aerobiology.

Luc BRAILLARD (2006)

**Morphogenèse des vallées sèches du Jura tabulaire d'Ajoie (Suisse): rôle de la fracturation et étude des remplissages quaternaires (224 pp.)**



**Abstract**

This work tackles the origin of the dry valleys of the tabular Jura of Ajoie (northwestern Switzerland) according to a new and multidisciplinary approach, in particular thanks to the geological information collected during the last twenty years in relation with the construction of the highway A16.

Once the geomorphological framework has been set, the various morphogenetic hypothesis found in the literature to explain the formation of the dry valleys are described and discussed. A comparative spatial analysis between micro-fracturing, macro-fracturing, and dry valleys confirms the tectono-karstic hypothesis of AUBERT (1969): dry valleys should be considered as linear uvalas, i.e. forms of dissolution similar to dolines, but that developed according to fracturing directions. However, the relation between dry valleys and fracturing is expressed only in combination with another parameter: the drainage direction.

The study of aerial photographs has confirmed the link between fractures and dolines, and clearly illustrates the process of the dry valleys formation by karstification. Assuming that dry valleys have a karstic origin, it is possible to deduce karstogenesis principles from the geometry of their patterns: in situations of low hydraulic gradient, the great tectonic faults play the role of collecting drains along which karstification operates. On the other hand, the strong hydraulic gradient which marks the zones with steeper topography favors the karstification along the fissures which are subparallel to the drainage direction, without taking into account their density. The layout of the galleries of the two underground rivers of the area (Milandrine and Ajoulote) in comparison with the fractures patterns confirms these principles.

Based on an integrated approach, including stratigraphic, tectonic and karstologic data, a reconstitution of the evolution of reliefs and rivers in Ajoie is then proposed. From the Eocene till now, five morphogenetic phases were recognized. The fourth and most important one corresponds to Jura folding and Bure plateau uplift, in late Miocene. Since the formation of these two structures, the hydraulic gradient has led to an intense phase of karstification which has modeled the present network of dry valleys and underground rivers. It was followed by a late plio-pleistocene phase which has given its current shape to the surface drainage.

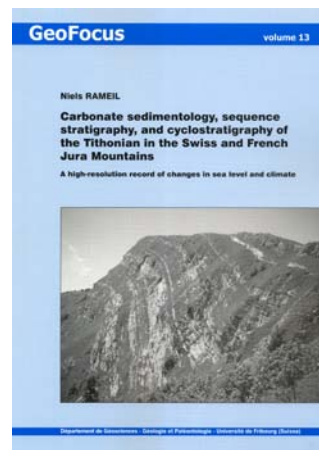
The detailed stratigraphic study of the quaternary fillings has allowed to establish a chronostratigraphic subdivision of the deposits in ten units. Fluvatile gravels constitute systematically the base of the fillings. They testify to a fossil drainage system, active during the Weichselian Early Glacial (OIS 5a-d) as well as Late Pleniglacial (OIS 2). OSL-dated Middle Pleniglacial loess (OIS 3) are intercalated between these two gravel bodies. Five fluvatile episodes have been found in the Holocene sedimentary record. The correlation of four of them with periods of high lake level in the Jura suggests that a climatic control (increase in precipitations) is responsible for these temporary reactivations of the superficial drainage.

In conclusion, a synthetic diagram of the formation of the dry valleys of Ajoie is proposed. It implies two erosive processes (karstification and fluvatile erosion) which are controlled by three parameters (tectonics, lithology, climate). The relative intensity of the processes and the role of the parameters vary according to the morphostructural compartments and to the periods considered. However, in their majority, the dry valleys can be considered as tectono-karstic furrows resulting from a primary

tectonic embrittlement, exploited and subsequently increased by karstic dissolution (main process) and fluvial erosion (accessory process).

Niels RAMEIL (2005)

**Carbonate sedimentology, sequence stratigraphy, and cyclostratigraphy of the Tithonian in the Swiss and French Jura Mountains (246 pp.)**



**Abstract**

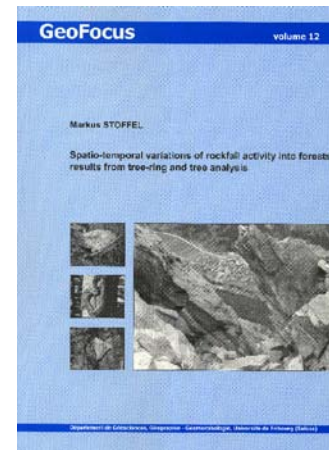
The present study aims at a better understanding of the development of the Swiss and French Jura platform during the Jurassic/Cretaceous (J/K) boundary interval, with a special focus on the Tithonian stage. Nine reference sections were measured in the Jura Mountains of north-western Switzerland and eastern France, in the Helvetic Alps, and in the Subalpine Ranges in south-eastern France. Their palaeogeographic position was on the north-western margin of the Alpine Tethys. Six of the sections are located in platform, one in slope, and two in basin positions, covering an interval of about 11 Ma from the Late Kimmeridgian (152.2 Ma) to the Middle Berriasian (141.0 Ma). In the Jura Mountains, the sedimentary record consists of a succession of lagoonal and peritidal carbonates that represent a shallow-water carbonate platform. The (hemi)pelagic (re)sediments studied in SE France and the Helvetic Alps were deposited on the slope and in the adjacent basins. Based on a detailed description and comprehensive sedimentological analysis of the reference sections the development and early diagenesis of the Late Jurassic/Early Cretaceous carbonate platform are interpreted. Stratiform, early dolomitization plays an important role in the Late Jurassic. Three different types of early diagenetic dolomite are observed and interpreted to represent three different dolomitization mechanisms: 1) a reflux-type mechanism that accounts for the majority of dolomite, 2) a dolomitization mechanism that depends on the presence of organic matter in burrow systems and is probably related to microbial mediation, and 3) dolomite that forms by evaporation near the surface of tidal flats. Massive dolomitization usually occurs in dolomite caps that define the upper parts of high-frequency shallowing-upward sequences. Sedimentary sequences occur on different scales. The stratigraphic record of the measured sections can be subdivided in elementary, small-scale, medium-scale, and large-scale (3<sup>rd</sup>-order) sequences. These sequences are superimposed on long-term (2<sup>nd</sup>-order) sea-level changes. The studied interval begins in the Late Kimmeridgian – a period of maximum creation of accommodation space, followed by a long-lasting regression into the Early Cretaceous. According to their estimated duration as inferred from biostratigraphic tie-points and their regular stacking pattern, medium-scale, small-scale, and elementary sequences can be interpreted in terms of cyclostratigraphy. Medium- and small-scale sequences are interpreted to represent the long and short eccentricity-cycle (400 and 100 ka respectively). Elementary sequences may in part relate to the 20 ka precession cycle but their record seems to be largely masked by noise that was generated by autocyclic processes, erosion, and/or non-deposition. Large-scale (3<sup>rd</sup>-order) sequence boundaries in the Jura Mountains usually consist of well-developed medium-scale sequence boundaries that were accentuated either by the superposition of the (orbitally induced) short-term fluctuations on the long-term trend in sea-level change and/or by regional tectonics. Using litho- and sequence stratigraphic markers and clay mineral data, a detailed correlation for the Late Jurassic and earliest Cretaceous reference sections on the Jura platform is established. Based on some rare biostratigraphic tie-points, the litho- and sequence-stratigraphic record from the platform is then linked to a large-scale sequence-stratigraphic framework derived from the biostratigraphically well-defined basin sections. This allows for a verification of the established sequence- and cyclostratigraphic timeframe by projecting biozones from the basin onto the platform and to relate lithologic changes observed in the basin to events or environmental changes that are much better recorded on the platform. It turns out that the developed sequence- and cyclostratigraphic framework correlates well with various European sequence-

stratigraphic studies and that the inferred timing from cyclostratigraphic analysis is well in tune with the sequence-chronostratigraphic charts of Hardenbol et al. (1998). For the first time, this allows studying platform development and environmental change around the J/K boundary in the Swiss and French Jura Mountains within a high-resolution timeframe.

Clay mineral analysis reveals a Middle to Late Tithonian episode characterized by a very low abundance of kaolinite (“kaolinite minimum zone”). The low abundance of kaolinite is interpreted to indicate the “Late Jurassic dry phase” that is known from all over Europe. Based on the developed cyclostratigraphic timeframe, the duration of the Late Jurassic dry phase in the Jura Mountains is inferred to have lasted 8.4 Ma. Moreover, the detailed lithostratigraphic data allow for subdividing the dry phase into a dry phase *sensu* (fully arid, desert-like climate) and a transition phase with a gradual change to semiarid, and winterwet conditions. A combination of sequence-, cyclo-, bio- and chronostratigraphic evidence supports the hypothesis that the beginning of the kaolinite minimum zone in the Jura Mountains is isochronous to the beginning of the kaolinite minimum zone in Dorset, southern England. Possible drivers for these major climate changes are discussed. The scenario considered to be most consistent with the sum of all observations is a change in oceanic current patterns in the Greenland-Norwegian seaway. The change in oceanic current patterns was probably linked to a combination of changing geometry of the Greenland-Norwegian seaway due to high rift activity and long-term sea-level evolution, both supposedly linked to a plate-tectonic reorganization that precedes the opening of the northern North Atlantic.

**Markus STOFFEL (2005)**

**Spatio-temporal variations of rockfall activity into forests –  
results from tree-ring and tree analysis (188 pp.)**



**Abstract**

Rockfall represents one of the most common geomorphological processes in mountain regions and has extensively been studied in the past. Nonetheless, detailed data on frequencies (*how often*), volumes (*how large*), spatial distributions (*where*) or the seasonality (*when*) of rockfall activity remain scarce and most of the time fragmentary. Similarly, tree-ring analysis has only exceptionally been used to investigate past rockfall activity. It was therefore the aim of this study to (i) assess intra-annual differences in rockfall activity and (ii) to investigate spatial and decadal fluctuations of rockfall activity on forested slopes with dendrochronological analysis. Furthermore, the vertical distribution of scars was investigated and the visibility of scars determined, before other strengths and weaknesses of dendrochronology in rockfall research were evaluated with extensive datasets from existing studies.

Firstly, 270 stem discs from 18 juvenile *Larix decidua* trees were prepared to study 25 years of intra-seasonal differences in rockfall activity on a forested slope at *Täschgufel* (*Täsch*, Swiss Alps). Based on approaches used to date past forest fires, the position of callous tissue and resin ducts has been assessed within the tree ring as to determine the intra-seasonal timing of events. Results show distinct differences in rockfall activity, indicating that rockfall is scarce during the vegetation period (12 %), which locally lasts from early June through mid October. In contrast, 88 % of the impacts occur during the winter dormancy of trees between mid October and the end of May. Direct observations on the slope confirm the results, indicating that rockfall activity would be highest around April and May, when global insolation on the west-facing slope gradually rises and ice lenses formed from meltwater slowly disappear in the joints and fissures of the rockfall source areas. In contrast, rockfall seems to be neither influenced by thunderstorms in summer nor abundant rainfall in autumn.

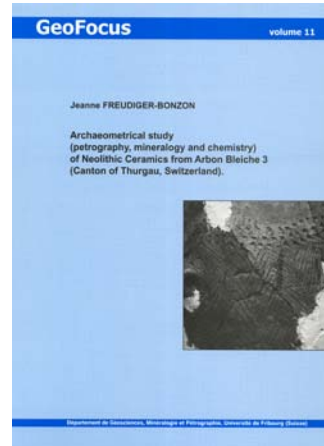
Secondly, 564 increment cores from 135 severely injured *Larix decidua* trees have been sampled at *Täschgufel* to investigate long-term spatial and temporal variations of rockfall activity. The analysis covers four centuries (1600–2002) and allowed reconstruction of 741 growth disturbances such as scars, traumatic rows of resin ducts, reaction wood and abrupt growth changes. Spatial analysis clearly shows that evidence from past rockfall events can commonly be found in trees located in the southern part of the slope, where they recurred more than once per decade. In contrast, trees in the northern part were less frequently disturbed by rockfall and locally define recurrence intervals of more than 150 years. Throughout the last four centuries, rockfall has caused growth disturbances to the trees sampled on the slope, most frequently in the form of low magnitude–high frequency events. In addition, analysis allowed identification of one high magnitude–low frequency event in 1720, which displaced the forest fringe of the northern sector a considerable distance downslope and eliminated an entire forest stand. Data further show that the forest recolonizing the southern sector after the 1720 event gradually improved its protective function, reducing the rate of reconstructed rockfall activity by a factor of 13 between the 1740s and the 1990s.

Thirdly, three adult trees (*Abies alba*, *Fagus sylvatica*, *Picea abies*) have been felled in the *Altdorfer Bannwald* (*Altdorf*, Swiss Prealps) as to investigate the height distribution and visibility of impacts (scars) on trees. Past impacts on trees were analyzed with 307 cross-sections taken every few centimeters between the stem's base and its crown. Results demonstrate that impact heights of rockfall fragments on trees largely vary depending on the diameter of rockfall fragments, the slope gradient as well as the forest cover.

As a consequence, scars were identified at heights ranging from almost 0 to more than 900 cm above ground.

Lastly and based on the results obtained from the three adult trees gathered at *Altdorfer Bannwald*, methodological difficulties, possibilities and limits of tree-ring analysis in rockfall research have been investigated. The study has been based on the idea that – in contrast to other hazardous processes such as debris flows, floods or wet snow avalanches – scars caused by rockfall activity are more randomly distributed on trees and may occur at largely varying heights. As a consequence, data gathered from nine different datasets in the Swiss Alps and Prealps have been analyzed in order to determine *inter alia* the percentage of scars remaining visible on the stem surface. Similarly, the number of scars reconstructed on entire trees has been compared to the events identified on only one cross-section or a series of increment cores taken at the height with a maximum number of wounds (i.e. test height) visible on the stem. Data indicate that the amount of overgrown scars would much depend on the bark properties of the species, yearly increment rates, the age of the tree, tree diameter as well as the size of rockfall fragments, resulting in an amount of ‘blurred evidence’ ranging from 15 to 90 %. Analysis of single cross-sections at a given ‘test height’ indicates that, at best, 13 to 35 % of the scars occurring on the entire tree can be detected. Data further suggest that the amount of events reconstructed at this ‘test height’ can be considerably improved as soon as other growth disturbances such as reaction wood, abrupt growth reductions or – if existing – traumatic rows of resin ducts are considered as well.

In conclusion, new insights about possibilities and limitations of tree ring–rockfall research have been gained in this thesis and comprehensive data obtained on the seasonality, frequency or magnitude of rockfall activity as well as the vertical distribution and visibility of scars on stem surfaces. Replicate studies have since proved the general applicability of the approaches developed. Nonetheless, further research is needed in general and at Täschgufer in particular, as there is potential for improvements and further research, namely on earthquake–rockfall or climate–rockfall interactions.



**Jeanne FREUDIGER-BONZON (2005)**

**Archaeometrical study (petrography, mineralogy and chemistry) of Neolithic Ceramics from Arbon-Bleiche 3 (Canton of Thurgau, Switzerland) (187 pp.)**

**Abstract**

This PhD thesis focuses on the findings from Arbon-Bleiche 3, a Neolithic lacustrine village on the Southern shore of Lake Constance (Bodensee, Switzerland). From 1993 to 1995, 1100 m<sup>2</sup> were excavated by the archaeological service of Thurgau (Leuzinger, 2000). The settlement was occupied during a very short period, fifteen years (3384-3370 BC) in the transitional period between Pfyn (3900-3600 BC) and Horgen (3200-2800 BC) cultures. Dr. A. De Capitani studied the ceramics from Arbon-Bleiche 3. She observed in the ceramics several characteristics of Pfyn culture and Horgen tradition.

She made a typological classification of the ceramics separating *Pfyn / Horgen pots* from diverse kinds of *special forms* divided into four sub-groups: *special forms Pfyn*, *special forms Baaern*, *special forms Boleraz* and *undetermined special forms*. *Special forms Pfyn* have characteristics from the Pfyn culture, *special forms Bayern* have specificities in relation with Altheim and Cham cultures in Bavaria, and *special forms Boléráz* were related to the Boléráz stage of the Baden culture (western Carpathian Basin). For De Capitani (2002), *Pfyn / Horgen pots* and *special forms Pfyn* were probably local. A research to detect a possible travel of the other *special forms* across Europe had to be made. This is the principal goal of this study. First, petrographical analyses permitted to separate non-ceramic material (cob fragments and loom weight) from the ceramics and spindle whorls. The first group was made of an inclusion-rich clay, without temper for the cobs and with organic temper for the loom weight. Inversely, the ceramics were manufactured with an inclusion-poor and silicate-rich clay and tempered in various ways. The ceramics were separated into ten petrographical group according to the clay used and the main temper added (i.e. granite, gabbro, chert, rhyolite, grog and bone). These groups were not in direct relation with the typological groups of De Capitani (2002).

Second, chemical analyses let three main groups separate: non-ceramic material (CaO-rich) vs. bone tempered ceramics (P<sub>2</sub>O<sub>5</sub>-rich) vs. the great majority of the ceramics from Arbon Bleiche 3. From an archaeological point of view, the *Pfyn / Horgen pots* are thought to be local. Moreover, because the ceramics cannot be chemically split into groups, the same provenance for the other ceramics is also proposed. Only 10 samples are outliers and werw surely foreign. However, a study of 14 ceramics from the western Carpathian Basin (probable import area defined by the archaeologists) did not match the chemistry of the outliers (except maybe one). Their provenance was, hence, not elucidated. Only their typological features are bound to Bavaria or to the western Carpathian Basin.

Reynald DELALOYE (2003)

**Contribution à l'étude du pergélisol de montagne en zone marginale (240 pp.)**



**Abstract**

The main objective of this thesis is the identification of mechanisms controlling the occurrence and the evolution of mountain permafrost in peripheral areas, i.e. where the presence of permafrost is strongly discontinuous, isolated, or even uncertain. This area has not been greatly studied so far. As investigations relating to the effects of climate warming on the alpine environment multiply, the comprehension of the mechanisms controlling the thermal regime of the ground in a situation of marginal permafrost takes on particular significance. Indeed, this type of permafrost should be a priori the first to completely disappear. About twenty sites mainly located in the western part of the Swiss Alps, but also in the Prealps, Jura and Pyrenees, were primarily investigated by means of electrical resistivity and ground temperature (instantaneous or continuous) measurements. Weather and snow data were also permanently recorded on several sites between 1998 and 2003.

Four types of terrain were analysed, namely :

- *scree slopes at low elevation* where permafrost can occur as low as 1200 m a.s.l. (above sea level) while the mean annual air temperature is higher than +5°C;
- *talus slopes at high elevation* (2200-3000 m a.s.l.) located near the lower limit of the discontinuous alpine permafrost belt, where the occurrence of permafrost is generally restricted to some portions of a slope;
- *inactive/relict rock glaciers* where materials can be preserved in a frozen state since several thousands of years ago;
- *historical (Little Ice Age) forefield* of small glaciers having often covered whole or part of pre-existing rock glaciers and where the current spatial distribution of permafrost is still marked by strong thermal and mechanical disruption caused by the glacier advance.

The results obtained support the assumption formed at the beginning of the work, namely that it is necessary to consider the spatial distribution of permafrost in an alpine environment as being the superposition of two modes in which the thermal mechanisms differ: a **typical** mode resulting from an energy balance whose components are primarily vertical (conductive and convective) heat fluxes, and an **atypical** mode mainly influenced by an advective component of the energy balance. At least two processes generating or having generated an atypical distribution of permafrost in non-consolidated sedimentary deposits can be highlighted : the **effects of the Little Ice Age glacier advance** and an **internal circulation of air** («chimney effect» or «wind tube»). One or the other of these processes may affect or have affected the permafrost conditions in any accumulation of materials and it is necessary to take this into account for a reliable estimate of the effects of the climate warming on the evolution and the spatial distribution of permafrost.

In the historical glacier forefields, the occurrence of permafrost is often limited to the margins of the former proglacial field. Frozen materials can be moved (formation of push-moraines) and significant imbalances, as much thermal as geometrical, can be caused by the glacier advance. In these strongly disturbed terrains, the effects of climate evolution are added to thermal adjustments in progress and can contribute to

accelerate the warming of permafrost which was moved (?) in certain marginal sectors of the proglacial field.

An air circulation which reverses and intensifies according to the contrast in temperature between the air in the interior of the blocky accumulation and the surrounding air could be shown in all the talus slopes of low and medium elevation that were analysed. The internal ventilation mechanism is crucial to allow the occurrence of permafrost in these talus slopes; in the lower part of a slope, it can indeed lead, depending on cases, to a thermal annual anomaly of the ground reaching 3 to 7°C compared to the mean annual temperature of the outside air. The winter ascending ventilation phase, causing a very strong cooling of the lower half of a slope, is not significantly blocked by a thick continuous snow cover. It is possible that such a circulation of air also contributes to determine the spatial distribution of permafrost in talus slopes at high elevation and to preserve materials in a permanent frozen state in inactive or fossil rock glaciers. Indeed, the available ground temperature measurements showed in any case the existence, certainly attenuated, of the ascending winter phase of the ventilation system.

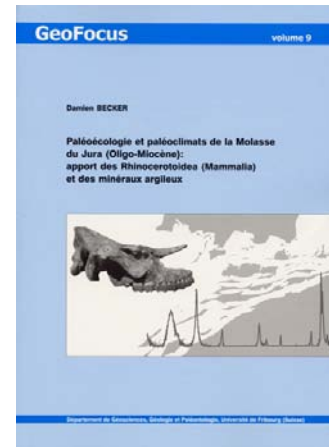
Part of this thesis is devoted to methodological questions concerning the relevance and the contribution of the used measurement techniques. An interpretation based on a qualitative - and not purely quantitative - approach of the obtained data is preferred.

Thus, for example, the detailed analysis of the aspect of the curve of a vertical electrical sounding allow us to highlight a possible heterogeneity of the ground composition and informs as much about the nature of the ground as the resistivities measured alone. A typology of characteristic curves was in addition drawn up within the framework of glacier forefield investigation. Concerning the measurements of ground temperature, BTS (Bottom Temperature of the winter Snow cover) measurements, for example, were used in preference for the identification of characteristics of the ground thermal regime rather than for the prospecting itself of permafrost. In addition, a typology of the annual thermal regime of the ground was defined to describe the effects and the specificities of the ventilation system in a low elevation talus slope.

The importance of repeating measurements in time (monitoring) is also underlined. Indeed, many original results suggested herein arise from measurements that were occasionally repeated or acquired in an uninterrupted way during several years. Unlike a simple prospection, monitoring does not only give a fixed image of the investigated situation, but also an evolutionary insight, which allows a better appreciation of it.

**Damien BECKER (2003)**

**Paléocologie et paléoclimats de la Molasse du Jura (Oligo-Miocène):  
apport des Rhinoceroidea (Mammalia) et des minéraux argileux  
(327 pp.)**



**Abstract**

The Jura Molasse, in which most remains of the studied Rhinoceroidea remains were found, constitutes a well preserved distal part of the Molasse Basin. This sedimentary series covered a major part of the Jura chain during the Oligocene and Miocene. Today, it is only sporadically found trapped in valleys or preserved in karst fillings. During the Oligo-Miocene period, the Jura region was considerably affected by hydrodynamic, tectonic and climatic changes as reflected by the marked variations of the heavy mineral spectra and the composition of the clay mineral assemblages.

The litho- and biostratigraphy of all Jura Neogene deposits were revised. Each formation used for the geologic mapping by former authors was listed, organized into a hierarchy and constrained to a biostratigraphical chart. A new lithostratigraphic scheme based on groups is proposed. This scheme allowed, in correlation with the Paleogene data of PICOT (2002), to draw a geologic map of the tertiary deposits in the Jura synclines.

About twenty new Tertiary outcrops are presented in detail. Their sedimentological and paleontological analyses allowed the reconstruction of the various depositional systems and a first paleoecological interpretation. The depositional environments of the Jura USM (Molasse alsacienne, Calcaires delémontiens), the gap of Aquitanian, the transgressive and regressive trends of the OMM, and the evolution of the fluvio-lacustrine systems of the OSM are illustrated.

The Super-family of Rhinoceroidea in Switzerland has been partially revised in terms of taxonomy. A biostratigraphical and paleoecological interpretation of this group is proposed. Results show that trends in diversity and anatomy types of the different taxa were controlled by paleoenvironmental changes, which, in turn, have been triggered by geodynamic processes from regional to global scale.

The recorded mineralogical changes and the evolution of Rhinoceroidea seem to be controlled by regional or global tectonic and/or climatic events. The Middle Eocene was characterized by a partially open forested environment, where only small and cursorial primitive forms of Rhinoceroidea evolved.

During the Late Eocene, no form of Rhinoceroidea has been reported in Switzerland. The forests became more dense and the climatic conditions remained warm and wet. The end of this period was marked by the "Grande Coupure".

The beginning of the Oligocene coincided with the occurrence of the first true Rhinocerotidae and the reopening of the forested environments. The climate seemed to deteriorate and became more arid (Mediterranean climate type). The Rupelian-Chattian boundary was marked by a tendency to cooling.

Chattian Rhinocerotidae presented weak, but perceptible predispositions to brachypody and hypsodonty. The climate continued to deteriorate and was marked by a crisis at the terminal Chattian as shown by the abrupt disappearance of palm trees and Taxodiaceae.

From the base of the Miocene, we notice a renewal in fauna within the Family of Rhinocerotidae. The environmental conditions improved and offered a wide range of biotopes.

The "Proboscidean Datum" characterizes the Burdigalian and Langhian boundary. The Family of Rhinocerotidae was strongly perturbed by Asian migrants, while again the climate changed in a more

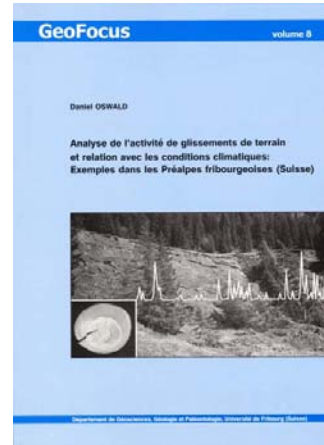
continental and arid way due to closure of the Tethys. During the Late Serravalian, a return to humid conditions was observed.

The last recorded stratigraphic interval corresponds to the mammal zone MN9, the base of the Late Miocene. Its lower limit is characterized by the "*Hippotherium* Datum", which opened the migratory corridor of the Bering strait. New migrants from Asia and Africa renewed the group of Rhinocerotidae. The environment remained forested. A relatively warm and wet climate, which had started in the Late Serravalian, persisted.

Due to the important position of the Jura Molasse as key for the paleogeographic reconstruction, the findings of the present study are of key importance in the Jura frame and beyond. A series of detailed maps illustrates the paleogeographic-palinspatic evolution of the Molasse Basin and of the Upper Rhine Graben according to eleven stratigraphic intervals from the basal Aquitanian up to the terminal Pliocene.

**Daniel OSWALD (2003)**

**Analyse de l'activité de glissements de terrain et relation avec les conditions climatiques: Exemples des Préalpes fribourgeoises (Suisse) (147pp.)**



**Abstract**

Deep landslides (> 10 m) are generally characterized by phases of acceleration alternating with periods of lull, but most often lack real stabilization. Due to the continuous movement, it is difficult to evaluate the evolution of the activity. Therefore, a new methodology has been developed in order to precisely identify the sub-recent (20<sup>th</sup> century) and present evolution of deep landslide activity, and to establish some predictions as for its future trends. This methodology represents an intermediate step between the recognition of instabilities (e.g., phenomena and hazard mapping) and investigations toward the stabilization of sites. To test and validate this methodology, three deep landslides located in the Prealps of Fribourg have been studied: The Hohberg landslide as reference site, and, for comparison, the Villarbeney and Falli Hölli landslides.

Variations in the activity during the 20<sup>th</sup> century were carried out using dendrogeomorphology. A method of analysis, developed in this project to study deep landslides, demonstrated not only a general landslide activity but also variations in accelerations of the intensity (approximately at annual scale). At the Hohberg landslide, increase of movements was observed in the beginning of the years 1950 and, since the middle of the years 1980, accelerations were intensified. The most active years were 1987-88, 1994, 1995, and 1999. The same analysis done on the Villarbeney landslide also indicated a growth of activity during the 1950. However, the main zone of this landslide showed a real decrease of the movements since the 1980, probably caused by anthropogenic influence (stabilization works). As for the Falli Hölli landslide, variations of activity recorded during the 20<sup>th</sup> century were similar to those of the Hohberg, but only until 1994. Indeed, the Falli Hölli landslide underwent a catastrophic event in the spring 1994 and remained "passive" thereafter.

Furthermore, measurements of displacements were done in order to accurately determine the phase of accelerations. At the Hohberg landslide, a major acceleration occurred in winter-springtime 1999 that can be constrained, particularly with using a laser measurement device that continuously records displacements (DICLAS). In the same way, on Falli Hölli landslide, successive GPS measurements led to precisely define the rate of displacements during the 1994 event.

The data of recent and present activity were compared to main climatic parameters that potentially influenced the stability, namely precipitations (raw and effective), temperature as well as rainfalls and snowfalls. The correlation tests were done at three distinct temporal scales: medium (multi-year scale), short (seasonal to yearly scale) and very short term (daily to monthly scale).

At the medium scale, relationships between general landslide activity and climatic conditions evolution were defined for a period of 20 years for the Hohberg landslide, 15 years for Falli Hölli, and 8 years for Villarbeney. These results demonstrated the high sensitivity of the Villarbeney landslide with regard to climatic variations, probably due to a volumetrically less active mass and a less extended watershed basin that reduced the water flow (recharge of the landslide). At the Hohberg site, yearly precipitations and rainfalls were identified as the most influent climatic parameters on the landslide activity. Furthermore, the influence of winter precipitations and rainfalls has been demonstrated. However, the impact of snowfall variations is minor in comparison to that of rainfalls. As for temperature, the correlations demonstrated an obvious link between increase in activity and warming on the medium scale. With regard to the Falli Hölli

landslide, the tests of correlations revealed almost identical relationships, except that no preferential link has been established between the rainfalls and snowfalls. As for the Villarbeney case study, no correlation was observed between landslide activity and temperature.

The study of influence at the short-term scale demonstrated that precipitations and rainfalls had an obvious impact on the major acceleration phases of the Hohberg landslide. However, snow and temperature had a minor influence. This general tendency, also valid for the site of Falli Hölli, has not been recognized at the Villarbeney landslide that seems less influenced by short-term climatic variations.

At the very short-term scale, specific climatic conditions were observed concerning the acceleration of the Hohberg landslide in 1999 and the catastrophic event of Falli Hölli in 1994. In both cases, melting during spring combined with rainfalls played a major role in acceleration triggering. In this case, all considered climatic parameters can be regarded as controlling factors of landslide stability.

The ultimate step of this study concentrated on forecast of the evolution of the studied landslides for the 21<sup>st</sup> century. The results, based on IPCC scenarios (IPCC, 2001; OcCC, 2002) indicated unfavourable trend for the Hohberg and Falli Hölli landslides. However, the impact of the melting ice cover at the medium scale remains uncertain. It seems unlikely that temperature increase estimated at 1.5 to 2 °C for 2050 can lead to the melting of the entire winter ice cover. Therefore, massive melting can be preserved. However, after 2050, it is likely that warming can lead to the melting of the entire winter ice cover. The spring melting will, thereafter, not longer influence the landslide activity. As for the Villarbeney landslide, the trend for the future landslide evolution cannot clearly be established, partly due to winter warming.

**Wolfgang Alexander HUG (2003)**

**Sequenzielle Faziesentwicklung der Karbonatplattform  
des Schweizer Jura im Oberoxford und unterstem Kimmeridge  
(154pp.)**



**Abstract**

During the Late Oxfordian and earliest Kimmeridgian, today's central Swiss Jura Mountains developed as a shallow carbonate-dominated platform. At the threshold between boreal depositional areas to the north and the Tethys ocean to the south, dynamic sedimentary systems developed under a subtropical and semiarid to arid climate (palaeolatitude 33° to 38° N).

Sedimentological analyses of the 6 reference sections Péry-Reuchenette, Pichoux, Court, Mettemberg-Soyhières, Liesberg 1, and Liesberg 2, as well as of 66 additional sections permit a detailed interpretation of the platform evolution in the central Swiss Jura.

The definition of 37 microfacies, 12 facies, 4 facies zones, and of facies periods within the 6 reference section is based on macro- and microscopic characteristics. These are described following detailed outcrop and thin-section observations. The main focus is set on the semi-quantitative analysis of the following microfacies elements: non-skeletal grains, skeletal-grains, terrigenous particles, and early diagenetic minerals. The facies zones are: external platform, barrier belt, internal platform, and coastal areas. Within these four zones, the following facies can be differentiated: reefs (coral reefs, microbial reefs), bars (oolitic, bioclastic, mixed oolitic-bioclastic, lithoclastic, and peloidal), lagoons in dependence of their position on the platform, aeolian deposits, emersion, beach, channels, ponds, tidal channels, and tidal flats.

Eustatic sea-level fluctuations, tectonic movements, and climatic changes affect the hydrosphere, the biosphere, and the morphology of the depositional environment. They are responsible for the character of the sediments and the depositional sequences, and thus for the development of the platform in general.

The depositional sequences are subdivided into different sequence types and into sequences of different orders. Elementary sequences are the smallest components of larger depositional sequences (small-, medium-, and large-scale sequences). It can be shown that they resulted from cyclic sea-level fluctuations in the Milankovitch frequency band. The duration of these depositional sequences therefore is 20 ka, 100 ka, 400 ka, and a multiple of 400 ka.

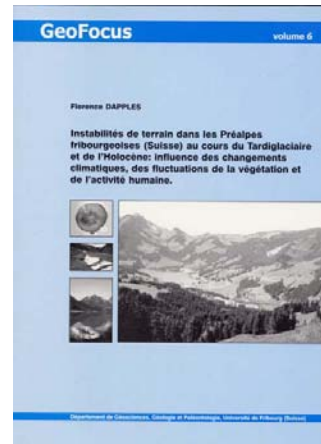
The key for a better understanding of the dynamic development of the platform is given by the correlation of the sections, based on biostratigraphic guidelines, on the knowledge of the general lithostratigraphic context, and on the high-resolution sequence- and cyclostratigraphic interpretation. A model defining different types of sequences (SB-, TS-, and MF-sequences) allows the reconstruction of a high-frequency sea-level curve.

The good sequential correlation of the platform sections leads to a comparison with the sea-level evolution from sequence boundaries Ox 6 to Kim 1 as suggested by Hardenbol et al. (1998), and also with the ammonites zones and the lithostratigraphy. The duration of the deposits between the two sequence boundaries inferred from cyclostratigraphy amounts to 1.6 million years (according to Hardenbol et al. 1998 about 1.8 to 1.9 Ma). This duration corresponds to four 400-ka cycles, within which sixteen 100-ka cycles and an average of seventy-four 20-ka cycles have been identified. This work shows that the combination of sequence- and cyclostratigraphy can contribute to a considerably refined dating of dynamic depositional processes.

Within the given narrow time framework, the formation of four oncoid types, the input of siliciclastics, and the differential subsidence are described and interpreted in the context of the climatic and tectonic platform evolution. It is shown that the effects of eustatic, climatic, and tectonic changes entail a pronounced dynamic evolution of the depositional environment. At the same time, perspectives are opened to persevere in studying the fascinating history of carbonate platforms.

**Florence DAPPLES (2002)**

**Instabilités de terrain dans les Préalpes fribourgeoises (Suisse) au cours du Tardiglaciaire et de l'Holocène: influence des changements climatiques, des fluctuations de la végétation et de l'activité humaine (158pp.)**



**Abstract**

Slope instabilities such as mudflows, debris flows or landslides have lately raised much concern in Switzerland, since various major events have occurred during last decade, resulting in major landscape disturbances, as well as costly damage to the infrastructure. This demonstrated the necessity to better understand the causes and dynamics of such processes. This research work aims at defining the complex relationship that prevailed, during Late Glacial and the Holocene, between the occurrence of mass movements and the fluctuation of external parameters such as climate, vegetation and anthropogenic impact. Various methods were carried out in order to collect data related to slope instabilities on the one hand, and to assess precisions concerning the fluctuations of paleoenvironmental conditions on the other hand.

The six following sites, located in the Fribourg Prealps, provided numerous data on slope instabilities since the end of the last glaciation: Hohberg, Falli Hölli, Schlossisboden, Pürrena, Villarbeney and Jaun. Prospecting was accomplished on each site, in order to collect fossil wood buried and preserved within unstable slopes. 69 wood samples were dated, through two distinct dating methods, according to sample volumes and preservation quality. Dendrochronology was applied on well preserved trunks exposing long enough tree-ring sequences, while radiocarbon dating was fulfilled on samples that could not fit any dendrochronological analysis. This lead to the creation of a 69-data series, associated with instability processes in the Fribourg Prealps. The consideration of each dating as unstable events gave evidence of the existence of recurrent phenomena such as mudflows, debris flows and landslides, during the past centuries and millennia. The present morphology and landscape of each site are the result of a succession of such unstable processes all along the past 15'000 cal years. However, prealpine slopes still suffer continuous modifications, related to present slope instabilities.

The gathering of all 69 datings generates an event chronology reflecting the activity of mass movements in the Fribourg Prealps during Late Glacial and the Holocene. The distribution of unstable events through time is quite heterogeneous. Distinct clusters of dates appear during specific periods of time, while a lack or a very low frequency of events characterizes other time intervals. Four periods of increased slope instability are defined: 11000-10250, 6250-4800, 3600-2100 and 1700-300 cal BP. This chronology of unstable events can be considered as a unique and high quality database in Switzerland and in Europe, since it contains a large amount of data and is associated with a large time interval covering the last 15'000 cal years.

This work also lead to an enriched knowledge of the activity of unstable slopes in Switzerland. New original data arising from Swiss study sites, coupled with existing published results, define a new chronology of past mass movements, concerning the whole Swiss territory. Five periods characterized by increased frequencies of slope instability are distributed along Late Glacial and the Holocene, among which the four most recent ones correspond synchronously with the Fribourg Prealps data. The five periods are: 14000-13000, 11600-10200, 7000-4800, 3750-2100 and 1900-150 cal BP. Such results give evidence of early mass movements occurring shortly after glacier retreat, as well as following the short-lived Younger Dryas glaciation.

A second approach of this research work was to specify the nature of controlling factors that affected prealpine and alpine slope stability during Late Glacial and the Holocene. We performed investigations in

order to collect local paleoenvironmental data that could be correlated with the slope instability records of the Fribourg Prealps. A 13m-long drilling was carried out in the Lac Noir (Schwarzsee) sediments. Palynological, sedimentological and mineralogical analyses were fulfilled on the lacustrine sediments and revealed very interesting and useful information about the evolution of the vegetation cover and the erosive context of the lake surrounding slopes. The close location of Lac Noir from the main instability study sites allowed the assessment of local comparisons between the chronology of mass movements and the fluctuation of environmental parameters. Synchronous correlations could be established between periods of increased activity of slope instability and periods associated with a reduction of woody areas. The increase of human-induced forest clearing, starting at 3650 cal BP, happens to coincide with the beginning of enhanced frequencies of mass movements. The major influence of vegetation cover on slope stability could be, therefore, demonstrated, at the scale of the Fribourg Prealps. Moreover, precisions concerning the Lac Noir history were brought to light, since an age of about 6100 cal BP could be proposed for the lake genesis. Such results tend to prove that Lac Noir was created long after the glaciers had retreated from the Singine valley. The lake creation most probably resulted from major mass movements that occurred during the mid-Holocene on the Schlossisboden site, located on the northern shore of the lake.

Beside the significant influence of vegetation fluctuations and anthropogenic activity on slope stability, the major factor controlling the activity of mass movements through time is climate, or more specifically climatic changes. The comparison between Fribourg and Swiss chronologies of slope instabilities and paleoclimatic records presented in published studies gives evidence of a very close correspondance between periods of high frequencies of mass movements and periods of climate deterioration. Such deteriorations, deeply affecting slope stability, are characterized by more humid and cold conditions. Such observations allow to considerate climate as the 1<sup>st</sup> order controlling factor of instability phenomena. All data and interpretations presented in this research work support and confirm the major role attributed to climate in the various processes of slope instability. However, the fluctuations of vegetation can be considered as 2<sup>nd</sup> order controlling factors of slope instabilities in the Fribourg Prealps during Late Glacial and the Holocene. The oscillations of the vegetation cover are not only associated with climatic changes, but also with the development of human settlements. The anthropogenic influence can, therefore, be considered as an indirect but still significant controlling factor of prealpine and alpine slope instability, since man affects slope stability and erosion processes by imposing continuous disturbances associated with agriculture development and landuse. This research work favoured the acquisition of numerous rich and original data related to the activity of slope instabilities during Late Glacial and the Holocene in the Fribourg Prealps.

Laurent PICOT (2002)

**Le Paléogène des synclinaux du Jura et de la bordure sud-rhénane: paléontologie (Ostracodes), paléoécologie, biostratigraphie et paléogéographie (240 pp.)**



**Abstract**

In the distal part of the Swiss Molassic basin, a typical foreland basin, the Jura Molasse is trapped within different synclines. This study focused on the paleogene deposits present in these synclines and as well as in the south border of the Graben. All formations mentioned in the literature were identified and a hierarchy was established. Each formation was defined and fixed on the biostratigraphical chart, allowing the construction of a new complete lithostratigraphy for the paleogene deposits. Based on this new lithostratigraphy, a geological map was established for the Jura synclines area.

Out of these paleogene deposits from the Jura synclines and the south border of the Graben, about thirty outcrops were studied in detail. Sedimentological, paleontological and biostratigraphical analyses allowed us to reconstruct marine, estuarine, fluviatile and lacustrine paleoenvironments.

A thorough paleontological study focused on the Ostracods. The totality of sampled ostracofauna was investigated and accurate taxinomial analyses, pertaining to its diagnoses, descriptions, as well as paleoecology were performed. Paleoecological models based on ostracods associations were developed. It is now possible to identify continental associations characteristic of lacustrine littoral zones and sub-littoral zones. A mathematical approach revealed the existence of typical marine associations, allowing us to define different marine paleoenvironments for the Rupelian Rhenish sea of the Jura synclines and the south border of the Graben.

To better understand lacustrine paleoenvironments, a study based on present-day lacustrine environments was undertaken which showed that the bathymetrical repartitions of fauna and flora are not hazardous. The occurrence of fructified charophytes gyrogonites is characteristic of depths of 0 to 4 meters. The abundance of epiphytal faunas like ostracods and gastropods is proportional to the space available on charophytes. Another important observation relevant to fossil lacustrine deposits, is how evolution of lakes and competition phenomena between Charophytes, Potamogetons and Myriophylles reveal the dynamics of these lakes, colonised first by pioneer hydrophytes (Charophytes), then gradually invaded by Potamogetons and Myriophylles which cause the regression and sometimes the disappearance of Charophytes.

This work also displays evidence for the existence of a marine link between the Rhenish sea and the perialpine sea during the Rupelian. This marine communication occurred through small sea channels exhibiting very specific paleoecological conditions, which only allowed a restricted fauna to prosper. These marine deposits are elusive, mainly because these sandstone levels are difficult to distinguish from these fluviatile sandstone deposits they cross. Rupelian fauna and flora from the perialpine and Rhenish seas show few affinities. One of the main reasons for this lack of affinity is the difference in paleoenvironments between perialpine position (epibathyal) and position (neritical, -30 m depth), leading to essentially different fauna and flora. On the other hand, fishes, which are active swimmers and therefore able to shirk from unfavourable ecological conditions, are common to both seas. A lot of reworked fauna and flora from the subalpine Paleocene deposits (planctonic foraminifera, dinoflagellates and nannofossils) are also present in the deposits of the Rhenish sea, and are further evidence of the once-existing marine communication.

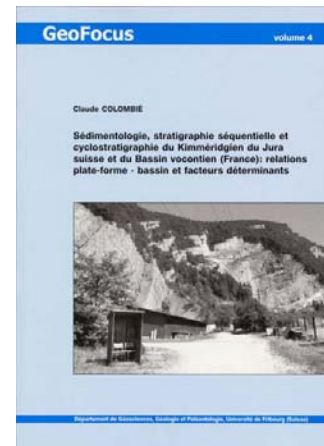
Ten paleogeographical maps have been established. The first five correspond to the Jura synclines zone, and the last five describe an area located between the Swiss alpine front and the north of the Graben. These maps show the modalities and the timing of the extension and eastward the regression of the perialpine

sea. The invasion of the Graben and the Jura synclines by the Rhenish sea is illustrated as well as its regression. The communication between the perialpine sea and the Rhenish sea is also represented and we surmise the existence of a marine connection between the south Graben and the Bresse Graben.

This study of the Paleogene deposits of the Jura synclines and the south-border of the Graben also presents geodynamical implications: The distension is recorded in the Jura as early as the Eocene-Oligocene boundary. Synforms resulting from the alpine folding are already present at the base of Rupelian, just like are present certain faults which cross the Vosges and Forêt-Noire massifs.

**Claude COLOMBIÉ (2002)**

**Sédimentologie, stratigraphie séquentielle et cyclostratigraphie du  
Kimmeridgien du Jura suisse  
et du Bassin vocontien (France): relations plate-forme – bassin et  
facteurs déterminants (198 pp.)**



**Abstract**

A detailed sedimentological, sequential and cyclostratigraphic interpretation of the Kimmeridgian in the Swiss Jura defines the principal factors which control the different stages in the development of a shallow-water carbonate platform. A comparative study in the Vocontian Basin reveals their impact on hemipelagic and pelagic sedimentation.

The sedimentary facies of three platform sections – Gorges de Court, Gorges du Pichoux, and Péry-Reuchenette – located to the North of Biel in the central Jura have been studied in great detail. Facies are representative of restricted to open-marine depositional environments. Low-energy lagoonal deposits such as mudstones and bioclast-peloid wackestones to packstones are dominant. Higher-energy grainstones composed of bioclasts, peloids, and ooids occur in lesser proportion. The analysis of the evolution through time of sedimentary facies, bed thicknesses, and sedimentological features of bedding surfaces results in a precise sequential and cyclostratigraphic interpretation of the Kimmeridgian in the central Jura. Different orders of depositional sequences are defined: elementary, small-scale, medium-scale and large-scale sequences, which are hierarchically stacked and suggest an orbital control on sedimentation. In order to confirm the cyclostratigraphic interpretation of the Kimmeridgian in the central Jura, where a precise biostratigraphic and chronostratigraphic framework is lacking, the platform sections are correlated with well-dated sections in the Vocontian Basin.

The sedimentological, sequential and cyclostratigraphic interpretation of three basinal sections – Montagne de Crussol, Châteauneuf d'Oze, and Gorges de la Méouge – leads to the definition of different orders of depositional sequences, which are comparable to the ones defined on the platform. The Vocontian Basin sections are correlated with the Jura sections according to the similarity that exists between the sequential and cyclostratigraphic framework defined in both realms. Thanks to the high-resolution platform-to-basin correlations, the Kimmeridgian chronostratigraphy defined in the Jura and in the Vocontian Basin is compared with the one proposed by HARDENBOL et al. (1998). The third-order sequence boundaries defined by HARDENBOL et al. (1998) in the Kimmeridgian of the Tethyan realm correspond to five medium-scale sequence boundaries revealed in the Jura and the Vocontian Basin. The third-order sequence duration given by HARDENBOL et al. (1998) is divided by the number of elementary sequences counted in the same time interval in the Gorges de la Méouge section, which is the section remotest from the Jura platform. According to these calculations, the duration of an elementary sequence is approximately equivalent to the 20 ky orbital precession cycle. Furthermore, small-scale sequences are generally composed of five elementary sequences, and medium-scale sequences contain four small-scale sequences. Assuming that an elementary sequence is equal to 20 ky, small-scale and medium-scale sequences coincide with the first and second eccentricity cycles respectively (i.e. 100 and 400 ky). The duration of the large-scale sequences is comprised between 800 ky and 1.2 My, which corresponds to the third order of VAIL et al. (1991). The studied interval is composed of 32 small-scale sequences or 8 medium-scale sequences, implying a duration of 3.2 My for the Kimmeridgian. This cyclostratigraphic interpretation is consistent with the radiometrically deduced duration of 3.12 My (GRADSTEIN et al. 1994, 1995; HARDENBOL et al., 1998). Consequently, the dynamics of the Jura platform and the Vocontian Basin were partly controlled by cyclic environmental changes induced by insolation variations in the Milankovitch frequency band. The combination of detailed sedimentology, sequence stratigraphy, cyclostratigraphy, and high-resolution

platform-to-basin correlation represents an excellent alternative to biostratigraphy for the dating of the Upper Jurassic shallow-water carbonate deposits, which are devoid of precise biostratigraphic markers.

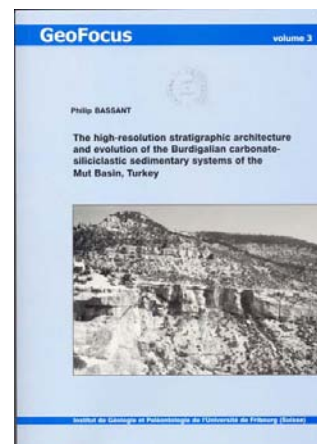
Analysis of stable isotopes and trace elements (Sr, Mg, Na, Fe, and Mn) has been performed in the Gorges du Pichoux section in order to confirm the high-resolution platform-to-basin correlation. The correlation between the variations of  $\delta^{13}\text{C}$  and trace elements defined on the platform and the ones available in the basin (DE RAFÉLIS, 2000) seems a priori difficult. However, the variations of  $\delta^{13}\text{C}$  and trace elements are consistent with the platform evolution during the Kimmeridgian, and their contribution to a better understanding of the global system is important.

The correlation of the platform sections reveals two parts with different characteristics, corresponding approximately to the Lower and Upper Kimmeridgian. The first part exhibits thinly bedded limestones with siliciclastics and desiccation features. The second part is characterised by thickly bedded limestones, the quasi-disappearance of siliciclastics and desiccation features, and the development of green algae. The transition between the Lower and the Upper Kimmeridgian corresponds to the strongest increase of accommodation recorded in the central Jura during the Kimmeridgian. Furthermore, the Lower Kimmeridgian comprises two different intervals, which correspond to large-scale sequences. The first one is comprised between the Platynota and Divisum ammonite zones and records a decrease of accommodation and carbonate production, while the second interval coincides with the Acanthicum zone and implies an important increase of accommodation and carbonate production. The two lower intervals correspond respectively to the late highstand deposit (IHD) and to the lowstand and transgressive deposits (LD and TD) of a lower-frequency depositional sequence, while the upper part coincides with the early highstand deposit (eHD). Finally, lateral variations of sequence thicknesses and the evolution through time of sedimentary facies reveal local to regional tectonic events, which occur in pulses during the Lower and Upper Kimmeridgian. According to the results obtained in this work, the decrease of accommodation and carbonate production between the Platynota and Divisum ammonite zones is probably due to the combination of a semi-arid climate with a prominent humid season and a eustatic sea-level drop. The increase of accommodation and carbonate production in the Acanthicum zone results from a more arid climate, an increased subsidence rate and/or a rise of eustatic sea-level. The same factors are probably responsible for the strong increase of accommodation and carbonate production that characterise the Upper Kimmeridgian. In conformity with southern England (TAYLOR et al., 2001), the most important gain in accommodation recorded in the central Jura coincides with the second-order Upper Jurassic transgression, which reached its maximum in the Eudoxus ammonite zone. This evolution is probably linked to major environmental changes due to global tectonics.

The sedimentological features of the Kimmeridgian hemipelagic and pelagic facies in the Vocontian Basin, the variations of carbonate production in the Jura and carbonate accumulation in the basin reveal that carbonate export from the platform to the basin is probably the controlling process for cycle formation in the Vocontian Basin. Different models combining carbonate productivity in shallow-water marine environments and carbonate export from the platform to the basin (influenced by several superimposed orders of sea-level fluctuations) are proposed for the generation of lower-frequency, large-scale, medium-scale, and small-scale sequences.

**Philip BASSANT (1999)**

**The high-resolution stratigraphic architecture and evolution of the Burdigalian carbonate-siliciclastic sedimentary systems of the Mut Basin, Turkey (278 pp. + annex in color)**



**Abstract**

The factors influencing the production and deposition of carbonate sediments are known. These are namely accommodation variations (eustasy and tectonics), siliciclastic sediment input, environmental changes (temperature, salinity, trophic level), nature of the producing ecologies, and the hydrodynamic regime. However, the manner in which these factors integrate through time to produce the diversity of stratigraphic architectures that we see is not well understood. This study addresses this question by describing the organisation of shallow marine carbonate-mixed platforms in three environmentally distinct contemporaneous settings across a basin. Chronostratigraphic correlations are made between the different sites, and this permits the comparison of coeval depositional facies and geometries, and the understanding of the factors that create the different stratigraphic architectures observed.

The study interval is the Lower Miocene (Burdigalian) of the Mut Basin in Southern Turkey. This area is chosen because it presents extraordinary large-scale 3D outcrops showing depositional geometries, and such outcrops are found throughout the basin.

The Mut Basin opened during the Oligocene and was partially filled by syn-extensional continental sediments. Post-extensional basin-wide thermal subsidence then occurred during the Lower Miocene, and at the same time rapid marine transgression flooded a complex relict topography, depositing shallow platform carbonates in a variety of settings, accompanied by some localised siliciclastic input.

The Miocene stratigraphy of two areas was mapped out in the field. This allowed three Burdigalian margin transects to be chosen for detailed study (Dibekli, Pirinç and Alahan). Observations of the stratal geometries and the facies were combined into a high resolution sequence stratigraphic framework of retrograding/prograding sedimentary cycles in order to construct stratigraphic cross sections of each transect. 3346m of section were logged, 400 thin sections were studied, and 145 biostratigraphic samples were analysed for nannoplankton dates (C.Müller). 10 samples were dated for planktonic foraminifers (R.Wernli). The three transects were then correlated: large-scale correlations were made by using the biostratigraphic dating, then high-resolution sequence stratigraphy and the construction of the relative sealevel curve for each site permitted correlation beyond the resolution of the biostratigraphy.

The first transect (Dibekli, Silifke region) has a steep asymmetric basement graben topography, forming a narrow strait, linking the Mut Basin to the Mediterranean, where strong tidal currents are generated. Siliciclastic input is low and localised. 80m of cross-bedded bioclastic sands are deposited in a tidal regime at the base. Subsequently carbonate platforms backstep against the shallow-dipping northern flank, while platforms only develop on the steep southern flank when a firm, wide shallow-marine area is provided by a fan-delta or the shallow-dipping top shoulder of the footwall. The energy of the environment decreases with increased flooding of the strait area.

The second transect (Pirinç, Mut region) is the open northern basin margin, and shows a complete platform-to-basin transition. An isolated platform complex develops during the initial flooding, which is drowned during a time of environmental stress, possibly associated with increased nutrient levels. The platform margin then retrogrades forming large-scale clinofold geometries, and progrades, before a major sea-level fall provokes slumping collapse, followed by rebuilding of the platform margin as sea-level rises again.

The third stratigraphic cross-section (Alahan, Mut area) is also on the northern basin margin. Here the siliciclastic input is high due to the presence of the palaeo-Goksu River bringing in dominantly fine grained sediment from an ophiolitic hinterland. The siliciclastic depocentre migrates landwards during transgressions, creating an ecological window allowing carbonates to develop in the distal part of the delta. Carbonate production shuts down during the progradation when siliciclastics return. Environmental pressure on carbonate growth is here coupled to the relative sealevel cycles that drive the transgressions and regressions. This motif is repeated at three different scales, and possesses a distinct hierarchical organisation.

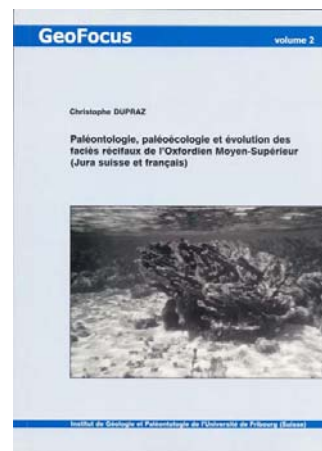
The stratigraphic architecture can be broken down into four scales of cycle, each with a characteristic amplitude and period. The very large-scale cycle, (period >3.4Ma, possibly non-periodic, amplitude of 200m) is attributed to a combination of glacio-eustasy and basinwide subsidence. Large-scale cycles (average period of <570Ka, amplitudes of 100-150m), and medium scale cycles (average period <100ka, amplitudes of 18-30m) are attributed to glacio-eustatic variations, possibly driven by astronomical eccentricity cycles. The small-scale cycles (average period 10-20ka, amplitudes 3-6m) are likely to be caused by other climatic changes, or autocyclic processes.

The tidal deposits in Silifke and the isolated platforms in Mut are shown to have developed contemporaneously: the dramatic difference in architectural style is due principally to the very different hydrodynamic regime, brought about by the basin topography.

The chronostratigraphic framework permits the recognition of condensation and omission surfaces in the basinal and platform settings, to identify basinwide variations in sedimentation patterns, and to evaluate the relative influence of tectonism, eustatism and the environment. The exceptional quality of the outcrops with its variety of environments, and its location at the Tethys margin make this a good candidate for a reference model for Burdigalian reef and platform architectures.

**Christophe DUPRAZ (1999)**

**Paléontologie, paléocéologie et évolution des faciès  
récifaux de l'Oxfordien Moyen-Supérieur  
(Jura suisse et français) (247 pp.)**



**Abstract**

The goal of this study was to determine the factors controlling the settlement and the growth of the coral-dominated reefs in the Oxfordian of the Swiss Jura Mountains, and to analyse how eustatic, climatic and trophic variations are recorded. These reefs developed on a relatively wide and very shallow sub-tropical platform, influenced by periodic siliciclastic input.

The coral composition is dominated by microsolenid corals. The analysis of the environmental distribution of this family, particularly of the genus *Microsolena*, suggests that it has developed a good adaptation to the heterotrophic mode of life. Its distribution in the patch-reefs is anti-correlated with the stylinid corals, which seem to be present only in the environmental optima. *Amphiastraea piriformis* and *Clausastraea parva* are adapted to harsh environmental conditions.

The microbolites display stromatolitic (laminated), thrombolitic (clotted), and leiolitic (structureless) fabrics. Macroscopic and microscopic study reveals that they commonly occur in two layers. The first one is directly in contact with the substrate and composed of leiolite (locally stromatolite) and a well-diversified micro-encruster fauna; the second one fills the remaining porosity partly or completely with thrombolite and low-diversity micro-encrusters. The growth of the first layer accompanies the growth of the coral reef and thus formed under the same environmental conditions. The second layer is the result of a moving encrustation front filling the remaining porosity (reef micro- and macrocavities) inside the reef, below the living surface. Both layers play an important role in early cementation. Phototrophic cyanobacteria are interpreted to intervene in the formation of the first encrustation zone, whereas heterotrophic bacteria associated to acidic  $\text{Ca}^{2+}$ -binding biofilms are interpreted as contribute to the thrombolite inside the reef body. When coral growth cannot keep pace with microbolite development, the thrombolite front reaches the surface of the construction and finally covers the reef. The result is a thick layer of thrombolite, which can be interpreted as being related to an ecological crisis in coral-reef evolution. A semi-quantitative analysis of the relative abundance of microbolite types and associated micro-encrusters permits to better constrain the processes leading to a reef crisis. Four micro-encruster associations can be distinguished, and each follows an evolutionary trend in the studied section: *Terebella-Tubiphytes* dominated, *Serpula-Berenicea* dominated, *Lithocodium* dominated, and *Bacinella* dominated. These trends are interpreted to reflect changes in environmental conditions.

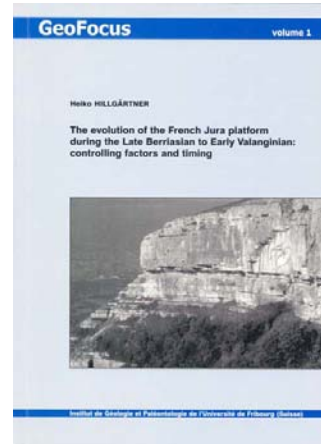
General facies evolution in the section and ecological composition of microbolite, micro-encrusters and bioerosion, in association with the taxonomical study of corals and macrofauna, made it possible to highlight trends in palaeo-environmental evolution, as a function of water turbidity, oxygenation, sedimentation, and nutrient content. Thus, the evolution towards a coral-reef crisis takes place in four main phases: (1) An oligotrophic to low mesotrophic phase when low water turbidity and good oxygenation allow a phototrophic metabolism. This leads to maximum coral diversity and development of light-dependent micro-encrusters. (2) A low-mesotrophic phase when increased turbidity and slack water circulation reduce the photic zone and favor heterotrophic micro- and macrofauna. Bioerosion through bivalves increases. (3) A high-mesotrophic phase when environmental conditions are so bad that only microbolite can be produced. (4) A eutrophic phase when carbonate production is inhibited by high nutrient input and clay flocculation as a result of increased terrestrial run-off.

The confinement inducing trophic evolution is linked to terrigenous run-off, which introduces nutrients and increases water turbidity, alkalinity, and sometimes siliciclastic accumulation. The terrigenous availability is a function of tectonics (responsible for emerged land) and climate (mainly humidity and seasonality

components). The heterogeneity (function of platform morphology, water circulation, and sea-level fluctuations) induces variations in space and time of chemical and physical confinement. Thus, using high-resolution sequence stratigraphy and cyclostratigraphy, it can be concluded that reef settlement, growth and crises are controlled by climatic fluctuations, linked to orbital cycles in the Milankovitch frequency band.

**Heiko HILLGÄRTNER (1999)**

**The evolution of the French Jura platform during the Late Berriasian to Early Valanginian: controlling factors and timing (203 pp.)**



**Abstract**

The objective of the present study is the understanding of the principal factors influencing the sedimentation of carbonate-dominated systems from the Late Berriasian to the Early Valanginian of the French and Swiss Jura (Pierre-Châtel, Vions, and Chambotte Formations). Climate, tectonic and eustatic changes are studied through analysis of facies, discontinuities, sequence-stratigraphy and cyclostratigraphy. The comparison with other paleogeographic settings, the hemipelagic to pelagic Vocontian Trough (France) and a mixed carbonate-siliciclastic ramp system in the Atlantic Atlas (Morocco), furnishes additional evidence on the interaction of factors controlling sedimentation and their temporal and spatial relevance.

Sedimentological analysis of 8 reference sections from the western Jura Mountains in France and 5 complementary sections from the central Swiss Jura, the French Vocontian basin and Moroccan Essaouira basin, permits the elaboration of depositional models of the Northern-Tethys and Atlantic margins in the earliest Cretaceous. The Jura platform was subdivided into a continental domain, coastal/tidal area, internal lagoon, open lagoon, barrier, and external lagoon. A ramp and slope/basin domain predominantly occur on the Atlantic margin and in the Vocontian Trough.

The importance of short-term breaks in sedimentation, which manifest the most rapid and substantial environmental changes in sedimentary systems, is taken into account by a detailed discontinuity analysis. On the basis of 8 criteria (geometry, lateral extent, morphology, biological activity, mineralization, facies contrast, diagenetic contrast, and biostratigraphy), the environmental relevance of discontinuity surfaces is assessed. Four groups of discontinuity can be distinguished, which are related to environmental changes indicating subaerial exposure, subaqueous omission, subaqueous erosion, and changes in texture and facies. Quasi-periodic environmental changes are expressed in the stratigraphic record through repetitive variations of sedimentological and geochemical characteristics. Three hierarchies of such depositional sequences are evidenced and can be attributed to the effect of relative sea-level changes. Deposits and discontinuities on all scales correspond to sea-level lowstand, transgression, maximum flooding, sea-level highstand, and regression. Elementary, small-scale, and medium-scale sequences can therefore be described in terms of sequence- and cyclostratigraphic concepts. Superimposition of different frequencies of sea-level change leads to the multiplication of characteristic discontinuities. Superimposed sea-level falls cause repeated formation of sequence boundaries (SB). Superimposed initial- and maximum floodings favor the formation of transgressive (TS) and maximum-flooding (MF) surfaces, respectively. On all scales, depositional sequences bounded by these discontinuities can be differentiated. SB-sequences are characterized by subaerial exposure surfaces and deepening-shallowing trends, whereas TS- and MF-sequences are delimited by discontinuities or intervals indicating initial flooding and deepening-shallowing trend, and maximum flooding and shallowing-deepening trend, respectively. The stacking pattern of the different types of depositional sequences reflects relative sea-level changes on a larger scale.

Integration of biostratigraphic data allows correlation of depositional sequences not only across the platform, but also with basinal sections and sections on the Atlantic margin. It suggests that medium-scale and probably also small-scale sequences reflect environmental changes of intercontinental extent. Typical arrangements of sequences in 5:1/4:1 relationships point to sea-level and/or climatic changes that were in phase with insolation variations in the Milankovitch frequency band. Elementary sequences, interpreted to

correspond to the precession cycle (20 ky), predominantly occur in the basin where the sedimentary system is less prone to the formation of autocycles, as compared to the highly dynamic platform environments. Small-scale sequences corresponding to the first eccentricity cycle (100 ky) are clearly evidenced on the Jura platform and in the Vocontian Trough, whereas on the Atlantic margin depositional sequences of a similar scale cannot be attributed to an external forcing factor. However, medium-scale sequences related to the second eccentricity cycle (400 ky) can unambiguously be correlated between Atlantic and Tethyan domains. Cyclostratigraphic analysis suggests a duration of 6 My for the studied interval (approx. 1.6 My for the Pierre-Châtel Fm., 2 My for the Vions Fm., 2.4 My for the Chambotte Fm.), which corresponds reasonably well to the radiometrically deduced duration of  $5.5 \text{ My} \pm 4.8 \text{ My}$  (Gradstein et al. 1995, Hardenbol et al. 1998).

The correlation within a narrow framework of timelines gives evidence for several intervals of differential subsidence, as indicated by contemporaneous deposition and condensation and/or subaerial exposure. Tectonic activity expressed as accelerated subsidence and blockfaulting is probably related to changes in stress patterns due to accelerated rifting in the North Atlantic, changes in motion between the African and European plates and initial rotation of the Iberian block. Tectonic activity in the *Picteti/Alpillensis* and *Otopeta/Pertransiens* ammonite zones is correlatable between Atlantic and Tethyan domains and coincides with major sea-level drops postulated on the “eustatic” sea-level curve of Haq et al. (1987). There is no evidence for major sea-level drops of comparable amplitude in either domain suggesting that the “eustatic” events indicated by these authors probably contain an important tectonic component. Sequence boundaries identified in the sequence-stratigraphic framework of Hardenbol et al. (1999) can be recognized, but they generally correspond to well-expressed boundaries of medium-scale sequences, whereas larger-scale, presumably 3rd-order relative sea-level trends, cannot be correlated between the studied domains.

Factors giving evidence for the general climatic evolution include subaerial exposures and associated diagenetic patterns underlined by stable isotope composition, siliciclastics (clay mineral composition, detrital quartz), presence and abundance of organic matter, and faunal assemblages. They indicate semi-arid conditions in the Purbeckian, a transitional climate for the Pierre-Châtel Formation, and more humid and seasonal conditions through the Vions and the Upper Chambotte Formations with a short (800 ky), more arid interlude in the Lower Chambotte Formation.

The evolution of the Jura platform as result of the interaction of eustatic sea-level changes, climate changes and tectonic activity can be summarized as follows:

1. After widespread progradation the Jura platform attained a flat-topped morphology at the end of the *Subalpina* zone (top Purbeckian). Tectonic activity initiated differential subsidence and/or local uplift during a lowstand in sea-level, which led to partial platform exposure (SB Be4). Resuming subsidence and a beginning sea-level rise on the 2nd order led to high-energy conditions in proximal platform positions on a now distally-steepened ramp morphology. However, effective carbonate production in a transitional, semi-arid climate and well-oxygenated environments allowed the platform to catch up with rising relative sea level and to prograde rapidly (early *Paramimounum* zone, Pierre-Châtel Formation).

2. Slowing relative sea-level rise, tectonic activity, and high-frequency, low-amplitude sea-level falls in the middle of the *Paramimounum* zone caused subaerial exposure with local karstification (SB Be5). Associated morphological changes in the hinterland, together with a more humid climate, explain the abrupt arrival of detrital quartz and organic material. For the duration of approximately 1 My the platform stayed in a state of keep-up as a result of continuing slow sea-level rise and low subsidence rates. The flat-topped platform morphology, attained through aggradation and progradation, recorded small-scale eustatic sea-level changes with widespread, repetitive exposures. The majority of siliciclastics and organic matter were trapped in shallow lagoons on the platform. This caused localized mesotrophic conditions, and the main area of carbonate production was thus restricted to the platform rim.

3. The sedimentary system began to change with elevated differential subsidence in the *Picteti/Alpillensis* zones. Tidal influence and strong currents became predominant on the highly structured platform that was marked by isolated barrier islands. A relative sea-level rise is recorded and is due to generally elevated subsidence, accelerated sea-level rise on the 2nd order, and low aggradation potential of the platform, in environments that were stressed by continuing detrital input.

4. The detrital input then gradually disappeared in the upper part of the *Alpillensis* zone as a response to a more arid climate and effective winnowing in predominantly high-energy environments. The backstepping of depositional environments and continuing differential subsidence led to a distally-steepened ramp morphology and absence of barrier systems in the lowest Chambotte Formation. However,

high carbonate production in the now oligotrophic environments again induced platform progradation and shoaling at the top of the *Otopeta* zone.

5. An abrupt tilt of the platform with significantly enhanced differential subsidence is evidenced by deep truncation and subaerial exposure in proximal platform positions and deep-ramp conditions with renewed siliciclastic input in more distal positions. A transitional climate with elevated seasonality is evidenced by high activity of storms and input of siliciclastics and organic matter. However, carbonate production was sufficient to compensate again for the subsidence pattern and induce local progradation (Upper Chambotte Fm.), only to be interrupted again by a phase of intensified differential subsidence and a platform crisis at the top of the *Campylotoxus* zone.

Short-term climatic and sea-level variations are responsible for bathymetric variations and facies distribution in platform and basin environments on a local to regional scale. However, depending on the general configuration and sensitivity of the sedimentary system, patterns of environmental change can be correlated over large distances. Climatic changes and episodic tectonic activity on the scale of 1 to 2 My mainly influence platform morphology, and presence and distribution of siliciclastics. This in turn influences to an important extent the efficiency of carbonate production and patterns of platform progradation, retrogradation and aggradation on a regional scale. Internal feedback mechanisms between sea-level change, plate-tectonic activity and carbon burial rates affecting the global carbon cycle act on the long term (several My) and control general platform evolution and the change between climate modes (e.g., Weissert & Mohr 1996). However, at least on a regional scale, such feedback mechanisms probably also led to higher-frequency fluctuations between climate modes (humid / seasonal / temperate-warm vs. semi-arid / balanced / hot) and to a highly irregular long-term trend with episodic set-backs leading towards the late Early Cretaceous greenhouse climax.