Ber. Inst. Erdwiss. K.-F.-Univ. Graz	ISSN 1608-8166	Band 9	Graz 2004

ADVANCES IN AUSTRIAN MIOCENE STRATIGRAPHY AND PALEOECOLOGY

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This brief report discusses some recent results that were achieved within the FWF-projects **P-13745-Bio, P-15724-Bio** and **P-14366-Bio** under the leaderships of Martin Zuschin (University Vienna), Gudrun Daxner-Höck (Natural History Museum Vienna) and Werner E. Piller (University Graz). The projects had a particular focus on the paleobiological aspects of marine molluscs and terrestrial mammals and on isotope signatures in the Austrian Miocene. The integration of geophysical logs and seismic data resulted in an improved understanding of sedimentary successions and associated changes in depositional environments throughout the Miocene of the Vienna and the Styrian Basin. These additional data were kindly provided by the OMV-AG (Berhard Krainer, Hanns-Peter Schmid and Philipp Strauss).

Sequence Stratigraphy (Eggenburgian, Karpatian-Pannonian):

During the running projects the integration of new biostratigraphic and paleoecological data resulted in a refined sequence stratigraphy of the Austrian Miocene. However, the Ottnangian and Lower Karpatian attained little attention during our studies and are therefore excluded here. Generally, it turned out that the major global 3rd order cycles as proposed by HAQ et al. (1988) and HARDENBOL et al. (1998) can still be depicted in the Central Paratethys depositional sequences despite tectonic overprint.

By focusing on the Pannonian Basin, VAKARCS et al. (1998) proposed two cycles for the Eggenburgian introduced as Bur-1 and Bur-2 cycles. These are bounded by the Aq-3/Bur-1 sequence boundary, corresponding tentatively to the Egerian/Eggenburgian chronostratigraphic boundary, and the Bur-2/Bur-3 sequence boundary which is correlated with the Eggenburgian/Ottnangian boundary. The mid-Eggenburgian sequence boundary separating the Bur-1 from the Bur-2 cycle is calibrated with the middle part of chron C6n. New investigations along the slopes of the Bohemian Massif by MANDIC et al. (2004) allow a finer tuning of the lower part of the Bur-1 cycle, corresponding to the *Oopecten gigas* Zone of the mollusc zonation. The lowstand systems tract of the Bur-1 cycle might be represented by the fluvial gravels and sands of the St. Marein-Freischling Formation, which fills the tectonically induced valley of the Horn Basin. The initial transgression seems to be reflected by the formation of the lowermost Eggenburgian Fels Formation on the margin of the Bohemian Massif. During the ongoing TST the sea intruded into the marginal drainage valleys of the Bohemian Massif and estuarine-lagoonal settings established. These are well reflected by pelites, coaly clays and lignite of the Mold Formation. The TST of the Bur-1 cycle falls apart into two up to now unrecognised parasequences, which document a drop of the realtive sea level of at least 30 m.

The first parasequence is very clearly developed and corresponds to the middle transgressive systems tract of the Bur-1 cycle and reflects the shift from estuarine towards shallow marine environments. It culminates in a lower shoreface facies with abundant crustacean burrows. The top of that transgressive parasequence with its related flooding surface is not preserved. However, it is still recognizable in the basal part of the following parasequence. There, the occurrence of *Oopecten gigas,* which is known to form monospecific populations in about 30 m water-depth, contrasts the otherwise littoral fauna of the coquinas with balanids, batillariids and mytilids. This paleoecological inhomogeneity is interpreted to be derived from reworking of an *Oopecten* layer during the second parasequence. This *Oopecten* layer is thus part of the "deep" top of the first parasequence, which became truncated by the second one.

The second "cycle", comprising units 3 and 4 is again distinctly transgressive and is tentatively correlated with the late TST of the Bur-1 cycle. The transgression is well reflected by a shift from shallow marine tempestitic shelly beds - that obviously formed above the wave base - towards a less agitated and sublittoral environment.
The following Bur-2 cycle is also excellently reflected in the area by the mollusc fauna, which suffers a drastic change in composition and displays a wave of Mediterranean immigrants during the transgression of the Bur-2 cycle (MANDIC and STEININGER 2003). This cycle, however, is not preserved in the discussed succession.

The sea level fall during the Early Miocene global sea level change of TB 2.1 cycle (HAQ et al. 1988) is reflected by isolation of the Paratethys from the Mediterranean Sea during the Late Ottnangian. Except for the Northern Alpine Foreland Basin no real marine environments are known from the Carpathian Pannonian Dinaride domain and brackish to fresh water sedimentary environments prevailed (KOVÁČ et al. 2004). The Karpatian transgression in the Central Paratethys area is associated with the sea level rise at the beginning of the late Early Miocene during the global sea level cycle of TB 2.2 cycle. The lowstand deposition represented mainly by terrestrial, alluvial, fluvial and deltaic deposits at the base of the Karpatian sequences, pass towards overlying strata rapidly into marine, neritic to shallow bathyal sediments. Due to the change of the tectonic regime during the Late Karpatian and Early Badenian small scale fluctuations of the relative sea level (e.g. 4th order) are probably only of regional character. The end of the Early Miocene in the Paratethyan basins is marked by erosional surfaces or by an angular discordance between the Lower and Middle Miocene strata.

The new Early Badenian (Langhian) transgression can be clearly correlated with the global sea level cycle of TB 2.3. cycle of HAQ et al. (1988), based on the FAD of *Praeorbulina* in the Styrian Basin, the Vienna Basin and the Alpine Foreland Basin (RÖGL et al., 2002). The global sea level drop at the Lower/Middle Miocene boundary was strongly accentuated by the change in the tectonic regime from a piggyback to a pull-apart basin. In the Vienna Basin, tilting of Karpatian deposits and erosion of up to 400 m occurred (WEISSENBÄCK, 1996). Hence, in the southern Vienna Basin, the sedimentation started discordantly during the Early Badenian with the deposition of the so-called Aderklaa Conglomerate, which is interpreted by WEISSENBÄCK (1996) as braided river system developing during the Lower Badenian LST. The sediment was transported from SE over the Leitha Mountains crossing the future Eisenstadt-Sopron Basin. This drainage system collapsed with the onset of subsidence in the Eisenstadt-Sopron Basin. The first marine ingression reached the Eisenstadt-Sopron Basin about 15.1 my ago and the Leitha Mountains became a peninsula connected with the mainland in the east (KROH et al. 2003).
The top of that Badenian cycle is indicated by an unconformity in seismic surveys in the southern Vienna Basin. Based on the co-occurrence of *Orbulina* and *Praeorbulina* in the underlying deposits (e.g. RÖGL et al., 2002) the boundary is suggested to have developed close to 14.8 ma. This massive discordance is also indicated in the central and northern Vienna Basin. A sea-level drop of about 120 m magnitude is also well documented in the Matzen oilfield (KREUTZER, 1986; WEISSENBÄCK, 1996). Furthermore, in many marginal settings e.g. the Northern Vienna Basin (Niederleis, Lower Austria) or in the Eisenstadt-Sopron Basin, the end of marine sedimentation of the first Badenian cycle can be correlated to the same event (MANDIC et al., 2002; KROH et al., 2003). The stratigraphic position, the basin-wide occurrence and the remarkable magnitude of the sea-level drop strongly indicate a relation to the global sea-level drop at about 14.8 Ma due to the expansion of the East Antarctic ice sheet (FLOWER and KENNETT, 1993). This event corresponds also to the Lan2/Ser1 sequence boundary of HARDENBOL et al. (1998).

The next Badenian cycle is interpreted to be an expression of the global cycle TB 2.4. of HAQ et al. (1988). A distinct lowstand wedge and a well-developed transgressive wedge are observed in seismic studies along the Spannberg ridge in the Matzen oil field of the central Vienna Basin (KREUTZER, 1986) and along the Leitha Mountains in the south (STRAUSS et al. submitted). During the HST a huge delta complex prograded into the central Vienna Basin. Wetland environments and deltaplain lakes developed along the southern margins, as documented by the mammal fauna of Klein Hadersdorf and freshwater limestones at Ameis. This cycle is separated from the third Badenian cycle by a weak discordance which is expressed by caliche formation and vadose leaching in the corallinacean platforms of the Leitha Mountains and the Rust Hills. The stratigraphic position of the associated sealevel drop suggests a correlation to the Wielician crises (deposition of evaporites in the Carpathian foreland basin caused by a sealevel drop that affected large parts of the Central Paratethys (RÖGL, 1998). The re-newed flooding of the third Badenian cycle is biostratigraphically dated in the Slovakian part of the Vienna Basin by the onset of the nannoplankton zone NN6 (KOVÁČ et al., 2004). The base of that biozone, being defined by the last occurrence of *Sphenolithus heteromorphus* corresponds to the Langhian/Serravallian boundary, which was recently calibrated by FORESI et al. (2002) at 13.59 Ma. Along the Leitha Mountains seismic reflectors associated with the TST are traceable up to the surface outcrop in Leithaprodersdorf where giant beach boulders of reworked Lower Badenian conglomerate document the impact of the transgression. Based on the good nanno-dating and considering the magnitude of the cycle a correlation with the global cycle TB 2.5. of HAQ et al. 1988 is quite convincing. The HST of that cycle corresponds with the formation of dysoxic pelites in basinal settings (e.g. Devinska Nova Ves) and with repeated hypoxid events on the platforms as documented by SCHMID et al. (2001).

A considerable hiatus at the Badenian/Sarmatian boundary is indicated by a strongly erosive discordance in seismic lines in the southern Vienna Basin. It is interpreted as part of the LST at the Badenian/Sarmatian boundary (HARZHAUSER and PILLER, 2004) coinciding with the formation of incised valleys along the margin of the Vienna Basin. The stratigraphic position and duration of the Sarmatian suggests a relation to the 3rd order cycle TB. 2.6. of HAQ et al. (1988), with two 4th order cycles. This tentative calibration requires a new positioning of the Badenian/Sarmatian boundary close to 12.7 Ma, which fits excellently to the glacio-eustatic isotope event MSI-3. At least 3 high-frequency sea-level drops have been observed in the Lower Sarmatian deposits of the Vienna Basin and the Eisenstadt Sopron Basin by HARZHAUSER and PILLER (2004). Of these, the most severe regression caused the emersion of the Leitha Mountains during the entire *Elphidium reginum* Zone and the lowermost *Porosononion granosum* Zone. This drop is thus reflected in the seismic facies by a basinal shift of coarse sedimentation represented by high amplitude reflectors. In both basins, a progradation of fluvial facies such as the Carinthian gravel in the Styrian Basin is observed. The Late Sarmatian starts with a strong transgression, partly covering Lower Sarmatian and Badenian deposits. The transgressive sediments are well developed along the margin of the southern Vienna Basin (HARZHAUSER and PILLER, 2004). Deposits of the following HST are known throughout the Vienna Basin comprising a mixed siliciclastic-oolithic cycle of the upper *Ervilia* Zone. This cycle is also well developed in the Styrian Basin (Southern Austria) discussed by KOSI et al. (2003) based on seismic stratigraphy. There it is reflected in aggradation and finally progradation of mixed siliciclastic-oolithic deposits.

The Lower to Middle Pannonian lake deposits are also interpreted as a single 3rd order cycle which starts at the Middle Miocene/Upper Miocene boundary due to the influence of the glacio-eustatic sea-level lowstand TB3.1. The LST of that phase is documented in the Styrian Basin by incised valleys of up to 60 m depth (KOSI et al. 2003). Correspondingly, fluvial gravel of the Hollabrunn-Mistelbach Formation was prograding into the northern Vienna

Basin during the LST of the Early Pannonian (HARZHAUSER et al., 2003b). At the same time fluvial gravel with *Melanopsis impressa* spread across Sarmatian marine deposits in the neighbouring Eisenstadt-Sopron Basin (HARZHAUSER et al., 2002). The pelitic and sandy deposits of the TST span the *Mytilopsis hoernesi* Zone, the *Congeria partschi* Zone and parts of the *Congeria subglobosa* Zone. Again, equivalent sediments are recorded by HARZHAUSER et al. (2002; 2003b) from the northern Vienna Basin and the Eisenstadt-Sopron Basin. The trend culminates in the mfs, which was documented in the northern and central Vienna Basin to lie within the *Congeria subglobosa* Zone (KOVÁC et al., 1998; HARZHAUSER and MANDIC, 2004). The comparison with geophysical logs from the Styrian Basin document, that oscillations of the lake level during the TST of that cycle are well reflected in both basins. Correspondingly, the maximum extension of Lake Pannon in the Middle Pannonian is documented in all Pannonian basins. Hence, the sedimentary record of the Vienna Basin reflects rather the "history" of Lake Pannon during the early Late Miocene than being exclusively an expression of local tectonics. The basal Upper Pannonian is part of the HST. At that time, Lake Pannon retreated from the Vienna Basin and established its north-western coast in the Hungarian basins (MAGYAR et al., 1999). Consequently, extended floodplains with local lacustrine systems developed (HARZHAUSER and TEMPFER, 2004).

Paleoclimate (Karpatian – Pannonian):

The Karpatian begins with a transgressive cycle, which introduced a series of new marine faunal immigrants from the Mediterranean. The Early to Middle Karpatian has still similarities with the Ottnangian development with cool to temperate water masses and abundant siliceous fossils (RÖGL et al. 2004). The low diversity mollusc fauna, too, is dominated by taxa persisting from the Ottnangian. In the Late Karpatian a general warming of the water masses is observed, especially in the shallow-water areas, reflected in the mollusc faunas which point to minimum sea surface temperatures of 15-17° (HARZHAUSER, 2002). Similarly, a Late Karpatian climatic amelioration can be reconstructed for the terrestrial realm, based on the data from the Korneuburg Basin, reflecting annual mean temperatures of about 17°C, minimum temperature of 3-8°C in the coldest period and precipitation up to 2000 mm (MELLER, 1998; BÖHME, 2002).

Despite the major drop of the relative sea level at the Burdigalian/Langhian (Karpatian/Badenian) boundary and the changing tectonic regime with the onset of pull apart kinematics, the overall climate signature stays constant. Hence, the Early Badenian is the heyday of thermophilic mollusc taxa such as *Isognomon, Tibia, Rimella, Melongena* and *Tudicla*, coinciding with the Burdigalian/Langhian climatic optimum. This phase is characterised by a northward migration of Mediterranean species into the Paratethyan Basins. Within the strombids, the rare *Strombus (Euprotomus) schroeckingeri* arrives in the Styrian Basin during the Early Badenian but could not reach the Viennna Basin or the Alpine Foreland Basin. A second strombid, *Tibia dentata* experiences an extraordinary bloom in the Early Badenian of the Styrian Basin, where its abundance is reflected in the informal term "*Rostellaria* Tegel" (= *Tibia* marls). It becomes extremely rare, however, in the Vienna Basin, where it is known from few fragments only. These patterns are discussed as an expresssion of a south-north gradient (HARZHAUSER et al., 2003a). The climatic optimum is also indicated by re-immigration of representatives of the Isognomonidae; this common element in the Oligocene to Early Miocene of the Central Paratethys disappeared during the Ottnangian crises. Additionally, the first occurrence of the Plicatulidae in the Central Paratethys Miocene in the Early Badenian is noteworthy. *Isognomon* and *Plicatula* are typical tropical representatives that are absent from the Modern Mediterranean Region. Similarly, the carditids, today restricted to the tropical and subtropical regions, diversified from 2 Karpatian species to 17 in the Early Badenian.

A slight cooling during the late Badenian is reflected by the retreat and/or decline of thermophilic mollusc taxa within the Paratethys. This is reflected e.g. by a decrease of the strombid diversity or by the drop in the nassariid genus *Cyllenina* from 9 Early Badenian species to 3 in the Late Badenian (HARZHAUSER and KOWALKE, 2004). According to these data a drop of the minimum sea surface temperature from at least 16-18°C during the Early Badenian optimum to 14-15°C in the Late Badenian is calculated. This Late Badenian cooling seems to succeed into the Early Sarmatian, indicated by the occurrence of diatomites and the dramatic shut down of the Badenian carbonate factory (PILLER and HARZHAUSER, in press). In the Late Sarmatian, however, the conditions changed strongly towards a subtropical, semi-aride environment. Indirect evidence for an increased aridity is derived from the fact that hardly any fluvial-terrestrial facies is preserved from that time-slice. The diverse Sarmatian floras are nearly restricted to the more humid Lower Sarmatian. The same hiatus is observed within the mammal faunas. The paleoclimatic considerations must therefore be based on the marine record. The Upper Sarmatian carbonate sequences reflect a highly productive carbonate factory of subtropical climate. The formation of thick oolite sequences with Persian-Gulf-type-ooids as well as the mass occurrences of thick-shelled shell beds require normal saline to hypersaline, subtropical conditions. The same subtropical environmental conditions are clearly necessary for the peneroplid, larger foraminifer *Spirolina austriaca* and other porcelaneous foraminifers. Also the isopachous, fibrous and the botryoidal cements, originally most probably aragonite, clearly point to carbonate supersatured, marine waters (PILLER and HARZHAUSER, in press).

Humidity increased distinctly again with the dawn of the Late Miocene. The small mammal faunas of the Early and Middle Pannonian (early Vallesian; MN9) indicate extended wetlands with humid, forested environments accompanied by dense vegetation during the maximum extension of Lake Pannon. The mammal fauna of the Late Pannonian (late Vallesian; MN10) comprises a high diversity of semi-aquatic, arboreal and gliding rodents. Nevertheless, the number of ground dwellers increases which might point to the successive spreading of open woodlands and to a trend towards advanced seasonality (HARZHAUSER et al., 2004).

The Latest Pannonian (early Turolian; MN11) mammal fauna is characterized by murid-cricetid-dominated associations and by a dramatic increase of carnivores (Hyaenidae) and ruminants (Bovidae and Giraffidae). The dominance of ground-dwelling rodents, the diversity of ruminants and the occurrence of the porcupine *Hystrix* hint at more dry conditions, a seasonal climate and relatively open woodland-environments. This faunal turn-over is synchronous with the so-called Vallesian crises – described from western Europe – and is thus the first evidence of that climatically triggered event in the Austrian Miocene (HARZHAUSER et al., 2004).

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Zeitschrift/Journal: Berichte des Institutes für Geologie und Paläontologie der Karl-Franzens-Universität Graz

Jahr/Year: 2004

Band/Volume: 9

Autor(en)/Author(s): Harzhauser Mathias

Artikel/Article: Advances in Austrian Miocene Stratigraphy and Paleoecology 11-17