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Egerian Deposits from the South-western Part of the Pannonian Basin, Croatia

Radovan Avanić, Koraljka Bakrač, Mirjana Miknić & Anita Grizelj

Egerian deposits occur only in north-western part of Croatia, i. e., Hrvatsko Zagorje Basin (Pavelić et al. 2003). Despite of many researches in that area, the stratigraphy of the Egerian deposits is still not clear.

New sedimentological, micropalaeontological and palynological analyses were carried out on the deposits from the lithostratigraphic column at locality Cerje Jesenjsko in Zagorje Basin, in the north-western part of Croatia, in order to define the boundaries between local formations: Meljan Formation (Lower Egerian) and Golubovec Formation (Upper Egerian). The deposits are grouped into three facies: massive to laminated marls and clays, normally graded sands and pyroclastic breccias.

Massive to laminated marls and clays dominate in the lower and middle part of the succession. They contain abundant foraminiferal association and numerous dinocysts. The association of foraminifera *Haplophragmoides carinatus*, *Cribrostomoides subglobosus*, *Reticulophragmium acutidorsatum*, *Vaginulinopsis gladius*, *Bolivina liebusi*, *Uvigerina mexicana*, *Cibicidoides similis*, *Heterolepa costata*, *Subbotina* cf. *galavisi*, *Globigerina ouachitaensis*, *Globigerina wagneri* and *Globigerinella megaperta* indicates Egerian age (Cicha et al. 1975; Rögl et al. 1998). Dinocysts are dominated by *Chiropteridium galea*, *Deflandrea phosphoritica*, *Homotryblium tenuispinosum*, *Polysphaeridium* sp. and *Spiniferites ramosus.* Dinocyst assemblages point out on *Chiropteridium* Abundance Subzone (Chi) – upper part of *Distatodinium biffii* Interval Zone (Dbi) of the uppermost Oligocene age (Brinkhuis et al. 1992).

The marls and clays were deposited on the shelf with terrestrial influence. In the upper part of the succession the respectable flow of pyroclastic material occur together with debris flow deposits at the top indicating re-deposition from shallow marine environment. Radiometric measurements that were carried out on andesites from the Lepoglava Quarry in vicinity, gave the K/Ar age of 22.8 ± 0.7 Ma (Šimunić & Pamić 1993). That data is in accordance with our palaeontological results, which suggest the Late Egerian age of the upper part of the succession.

The sedimentary succession on the Cerje Jesenjsko locality, starting with shelf deposits and ending with prodelta deposits shows coarsening-upward tendency, and generally suggests progradation of the delta system.

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Middle and Upper Miocene Palynology from the South-western Parts of the Pannonian Basin

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Palynological characterization of the Middle and Upper Miocene deposits from the Croatian part of the Pannonian Basin has resulted in a palynological zonation of the compositional development of the successive dinocyst assemblages. Seven characteristic palynozones of regional palynostratigraphic range and eight local subzones can be recognized.

The first zone is *Unipontidinium aquaeductum* Zone, of Badenian age. The leading form is from deeper and distal environment, associated by *Nematosphaeropsis lemniscata*, *Batiacasphaera sphaerica* and *Impagidinium patulum.* It could be correlated with Mediterranean zone of the same name *Unipontidinium aquaeductum* – LAN6, from the Serravallian of Italy (Powell 1986; Zevenboom 1995). During Badenian, based on the following dinocyst assemblage: *Systematophora placacantha*, *Spiniferites* spp., *Operculodinium* spp., *Hystrichokolpoma cinctum*, *Melitasphaeridium machaerophorum*, *Systematophora placacantha* Zone is defined in proximal, open marine environment.

Sarmatian *Polysphaeridium zoharyi–Lingulodinium machaerophorum* Zone is characterized by relatively rich marine community, but the most forms are euryhaline like *Polysphaeridium zoharyi* and *Lingulodinium machaerophorum*. Prasinophyta genera *Leiosphaeridia*, *Tytthodiscus*, *Hidasia* and *Mecsekia* are very important in the Sarmatian *Cymatiosphaera miocaenica* Zone, which characterizes stratified environment.

Lowest Pannonian *Mecsekia ultima* Zone is, also, characterized by the domination of prasinophyts, especially by the genera *Mecsekia*.

The succeeding zone is the *Spiniferites bentorii* Zone that can be correlated with the same named zone in Hungary (Sütő-Szentai 1988). Based on the dominance of the following species it is subdivided into three subzones: *Spiniferites bentorii pannonicus*, *Spiniferites bentorii oblongus*, and *Pontiadinium pecsvaradensis*. In the upper part of this zone few Mediterranean dinocyst species are recognized, indicating communication between Mediterranean and Paratethys at that time.

The beginning of the succeeding *Spiniferites balcanicus* Zone is defined by the dominance of the same species. This zone characterizes the Upper Pannonian deposits.

The assemblages of the upper part of the *Spiniferites balcanicus* Zone are similar to the Hungarian *Spiniferites balcanicus* Zone (Sütö-Szentai 1988).

The dominance of the *Galeacysta etrusca* marks the beginning of the *Galeacysta etrusca* Zone. This zone characterizes uppermost Pannonian distal deposits and it can be correlated both, with same named zone in Hungary (Sütö-Szentai 1988) and the Messinian "lago-mare" in Italy (Zevenboom 1995). It can be separated into subzones *G. etrusca–Spiniferites virgulaeformis* and *G. etrusca–Spiniferites cruciformis*.

After disintegration of the Central Paratethys at the end of Sarmatian, and the rise of Lake Pannon, two main transgression-regression cycles are documented in the Upper Miocene deposits. During the maximum transgression of the first cycle in the Middle Pannonian (= "Pannon E" sensu Papp et al. 1985; = "Upper Pannonian" sensu Stevanović et al. 1990) Mediterranean dinoflagellates migrated into the Pannonian Basin. The connection with the Eastern Paratethys established at the end of Pannonian (= "Upper Pontian" sensu Stevanovic et al. 1990; Magyar et al. 1999) and enabled the endemic Lake Pannon dinoflagellate taxa to migrate via Eastern Paratethys into the Mediterranean.

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Predatory Drill Holes on Ostracods from the Upper Miocene Long-lived Lake Pannon at the Locality St. Margarethen (Burgenland, Austria)

Robert BUTTINGER & Martin ZUSCHIN

Predatory drill holes are well known from Cenozoic marine molluscan assemblages, where they can mostly be attributed to the activity of muricid and naticid gastropods. Similar drill holes are also reported from marine ostracods, but to our knowledge have not been described yet from a lake ecosystem. We studied the ostracod assemblages from the Upper Miocene Lake Pannon at the outcrop "Altes Zollhaus" at St. Margarethen, Burgenland. The sediments of this outcrop belong to the Lower Pannonian ("Pannon B–D"; local stage corresponding to the Lower Tortonian mammal zones MN8 and MN9), and consist of silts, sands and gravels, deposited in a mixo-mesohaline lake environment. Ostracods were abundant throughout the studied transect with a thickness of 20 m and are represented with typical Pannonian assemblages, consisting mainly of *Cyprideis*, *Hemicytheria*, *Amplocypris* and candonids. Drilled valves occurred in gravelly and sandy layers in the uppermost part of the section ("Pannon D"; Fig. 1).

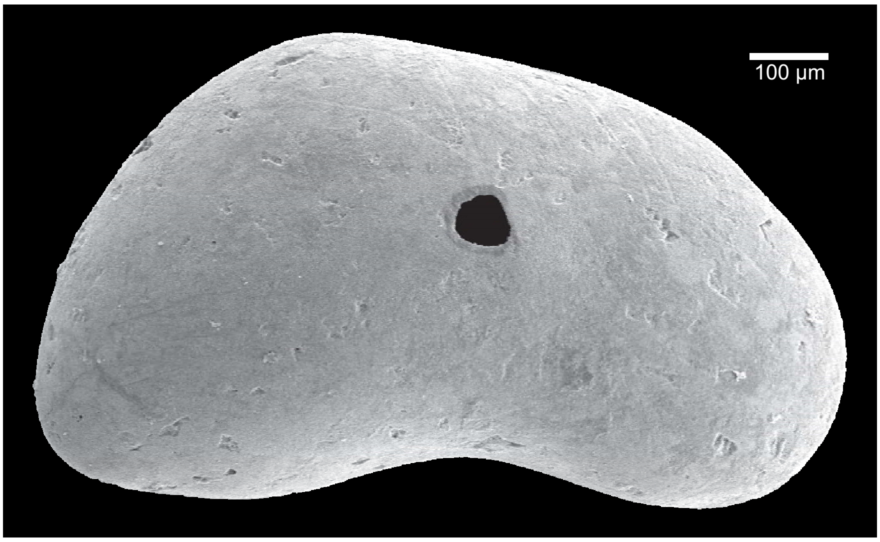

Fig. 1: Drill hole on an adult *Candona* sp. from St. Margarthen ("Pannon D").

Drill holes were only found on three valves of *Amplocypris recta* (length 1.16 mm), *Candona* sp. (1.04 mm) and an unidentified cyclocypridid specimen (0.56 mm). *Amplocypris* and *Candona* are most likely autochthonous, the cyclocypridid species is a freshwater form that was probably transported from a deltaic system to the west into Lake Pannon. The perforations in the valves are single, almost circular in plan view, drilled from the outside and have bevelled edges; they are therefore interpreted as predatory in origin. All drilled specimens are adult; the drill holes are very small (outer drill hole diameters range from 0.07 to 0.23 mm).

The producers of the drill holes are unknown, drilling gastropods do not occur in Lake Pannon and nothing is known about potential other drillers in this fossil long-lived lake.

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Stratigraphical Position of *Helicosphaera waltrans* Nannoplankton Horizon (NN5, Lower Badenian)

Stjepan Ćorić, Lilian Švábenická, Fred Rögl & Pavla Petrová

In the last few years Badenian sediments were studied through scientific projects at the localities of Austrian and Czech Republic parts of the Central Paratethys. Calcareous nannofossil and foraminiferal content of Lower Badenian sediments yielded new important stratigraphical data. A short biohorizon with *Helicosphaera waltrans* (described by Theodoridis 1984 from Gozo, Italy) within nannoplankton zone NN5 (*Sphenolithus heteromorphus* Zone; Martini 1971) was used for the subdivision of Langhian sediments in the Mediterranean (Theodoridis 1984; Fornaciari et al. 1996).

Helicosphaera waltrans horizon was also recognized in the Lower Badenian sediments of the Carpathian Foredeep (Švábenická 2002) and used as a marker of zone NN5 (Ćorić & Švábenická 2004). Species *H. waltrans* was recorded in the following depositional areas of Central Paratethys.

Alpine-Carpathian Foredeep

Grund Formation (Austrian part): borehole Roggendorf-1 and Grund section. *H. waltrans* was also observed in the assemblages with high percentage of *Coccolithus pelagicus* in siliciclastic sediments of the Gaindorf Formation (Mühlbach at the Manhartsberg, Lower Austria). *H. waltrans* was found in the outcrops of Central Moravia (Czech Republic) near Olomouc (localities Opatovice HJ-103, Šatov, Troskotovice, Hradčany, Kelčice (Švábenická 2002). Shallow water deposits of boreholes Ivan-1 and Vranovice-1 (located SE from Brno) contained *H. waltrans* with common specimens of genus *Micrantholithus* sp. and *Braarudosphaera bigelowii.* Overlying strata yielded nannofossils with alternating high numbers of small reticulofenestrids (forming 20–55 % of assemblage) and *Coccolithus pelagicus* (30–70 %). Here, the first occurrence of *H. waltrans* precedes first occurrence of foraminifer *Orbulina suturalis* (Petrová & Švábenická 2007).

Vienna Basin

In the Austrian part *H. waltrans* was found in marly sediments from Frättingsdorf (with diatoms and silicoflagellates) and at the sections of Niederleis. Foraminiferal assemblages here contain *Orbulina suturalis* and *Praeorbulina glomerosa circularis*.

In the Czech part (South Moravia) this species was found in association with *Helicosphaera walbersdorfensis, Sphenolithus heteromorphus, Calcidiscus* cf. *tropicus* and relatively common *Umbilicosphaera rotula* at the locality of Sedlecký mlýn, SE from Mikulov.

Styrian Basin

This biohorizon outcrops in the Wagna quarry, at Retznei (Rögl et al. 2006; Lirer et al. 2006) and Katzengraben (near the Slovenian/Austrian border). Horizon with this form was also observed in sediments from borehole Perbersdorf 1 (Spezzaferri et al. 2004). Sediments from the Styrian Basin are characterized by very abundant and well-preserved nannoplankton assemblages with the dominance of small reticulofenestrids: *Reticulofenestra minuta* and *R. haqii*. Regularly occur *Coccolithus miopelagicus*, *C. pelagicus*, *Calcidiscus premacintyrei*, *C. leptoporus*, *Discoaster varaiabilis*, *D. deflandrei*, *Geminilithella rotula*, *Pontosphaera multipora*, *Reticulofenestra pseudoumbilica*, *Sphenolithus heteromorphus*, *S. moriformis*, *Umbilicosphaera jafarii*, helicospherids (*Helicosphaera carteri*, *H. euphratis*, *H. walbersdorfensis*). Rare *Helicosphaera ampliaperta* (NN2–NN4) in these sediments is probably the result of the reworking from underlying Karpatian sediments.

Planktonic foraminiferal assemblages of the biohorizon with *H. waltrans* are typical for the Lower Lagenidae Zone (Rögl & Spezzaferri 2003): *Praeorbulina glomerosa glomerosa*, *P. glomerosa circularis*, *Orbulina suturalis*, *Globorotalia bykovae*, *G. transsylvanica*, *Paragloborotalia mayeri/siakensis*, *Globigerinoides bisphericus*. Also occur important benthic species: *Uvigerina macrocarinata*, *U. uniseriata*, *Vaginulina legumen*, *Lenticulina echinata*, *Psammolingulina papillosa*, *Pseudogaudryina lapugyensis*, *P. sturi*, *Colominella paalzowi*.

Rich calcareous nannoplankton and foraminiferal assemblages from biohorizon with *H. waltrans* are related to the Lower Badenian transgressive phase.

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Biostratigraphy of Middle Miocene Sediments from the Tuzla Basin (North-eastern Bosnia) Based on Foraminifera and Calcareous Nannoplankton

Stjepan Ćorić, Sejfudin Vrabac, Zijad Ferhatbegović & Izudin Đulović

The Tuzla Basin (NE Bosnia), situated on the southern periphery of the Central Paratethys, was a gulf during Miocene. The thickness of Miocene sediments is about 2300 m. Petrović (1979/80) and Vrabac et al. (1990) reported about the stratigraphical position of Miocene sediments from the Tuzla Basin based on foraminifera. Foraminifers and calcareous nannoplankton from Miocene sediments were newly investigated from outcrops in the Tuzla area, and from the borehole Tetima (B-77) located 12 km NE from Tuzla. The borehole is placed in the Dokanj syncline in the south-western edge of Majevica horst anticlinorium. This investigative-exploitation borehole (B-77) was drilled during 2005, and recovered salt formation at depth about 407 m.

Foraminifera

Lower Sarmatian sandy marls and sandstones from the uppermost part of the investigated section (about 25 m) contain very rare foraminifera (*Elphidium* sp.) and molluscs: *Mohrensternia* sp. and *Hydrobia* sp*.* According to the specific association of fossils these Lower Sarmatian sediments can be correlated with *Rissoa* Beds. This stratigraphic unit corresponds to the local *Anomalinoides dividens* foraminiferal zone. Upper Badenian sediments belong to the local *Bolivina dilatata maxima* zone (sample from 32 m). Foraminiferal assemblages of this zone contain *Globigerina bulloides*, *Pappina parkeri*, *Bulimina elongata elongata*, *Uvigerina semiornata* etc. Middle Badenian sandy marls and sandstones contain a fauna characteristic for *Pappina parkeri* local zone. The investigated sediment is from 85 m depth. Lower Badenian sediments are palaeontologically defined in an interval from 125–400 m. According to foraminiferal assemblages this interval can be subdivided into two local zones: *Ammonia viennensis–Nonion commune,* and *Globigerinoides trilobus–Orbulina suturalis*. In the local *G. trilobus–O. suturalis* zone*,* which is recognized from 125 to 340 m, occur: *Uvigerina macrocarinata*, *U. pygmoides*, *Lenticulina inornata*, *Globigerina bulloides*, *Globoquadrina altispira*, etc. The *A. viennensis–N. commune* assemblage points to shallower deposition depth.

Calcareous nannoplankton

In total, 77 samples for nannoplankton were quantitatively analysed in the interval from 23 to 400 m from borehole B-77. Analysed sediments from 23 to 125 m do not contain *Sphenolithus heteromorphus*, and therefore they can be included in nannoplankton zone NN6. Nannoplankton association contains high percentage of *Reticulofenestra pseudoumbilica* (5–7 μm) form. Following forms are present in this interval: *Calcidiscus leptoporus*, *Calciosolenia murray*, *Coccolithus pelagicus*, *Coronosphaera mediterranea*, *Helicosphaera carteri*, *H. minuta*, *H. walbersdorfensis*, *H. wallichi*, *Holodoscolithus macroporus*, *Pontosphaera multipora*, *Reticulofenestra gelida*, *R. minuta, R. haqii*, *Rhabdosphaera sicca*, *Sphenolithus abies*, *S. moriformis, Syracosphaera pulchra* and *Umbilicosphaera jafari.* According to the LO of zonal marker *Sphenolithus heteromorphus,* the NN5/NN6 boundary is placed between 230 and 235 m. All investigated samples from 235 m downward to the salt formation (to 395 m) contain this form and can be attributed to biozone NN5 (*Sphenolithus heteromorphus* Zone; Martini 1971). The most frequent forms in this zone are small reticulofenestrids: *Reticulofenestra minuta* and *R. haqii* (>80 % of total nannoplankton association). Also occur: *Coccolithus miopelagicus*, *C. pelagicus*, *Cyclicargolithus floridanus*, *Geminilithella rotula*, *Helicosphaera carteri*, *H. walbersdorfensis*, *Pontosphaera multipora*, *Reticulofenestra pseudoumbilca*, *Sphenolithus moriformis*, *Syracosphaera pulchra* and *Umbilicosphaera jafari*.

Based on the changes in percentage of *H. heteromorphus,* nannoplankton Zone NN5 can be subdivided into two subzones: 1) from 235 to 395 m with *S. heteromorphus* up to ca. 20 % and 2) from 395 to 400 m with significant lower content of this form (up to ca. 5 %). It is important to mention that these two intervals correspond to local foraminiferal zones: the zone with high percentage of *S. heteromorphus* can be correlated with the *G. trilobus–O. suturalis* local zone, while the zone with lower percentage of *S. heteromorphus* corresponds to *A. viennensis–N. commune* zone.

Sediments of the local *A. viennensis–N. commune* zone, above salt formation were stratigraphically positioned into the Karpatian before. New results of calcareous nannoplankton analyses of sediments from the borehole B-77 allow now a correct attribution of this local zone into nannoplankton Zone NN5, and belong therefore to the Lower Badenien.

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Taxonomic Diversity of Middle Miocene Ostracod Assemblages – A Useful Tool for Palaeoenvironmental Characterization of the Hainburg Area (Vienna Basin)

Dan L. DANIELOPOL, Martin GROSS & Werner E. PILLER

Diversity of a given organismic assemblage can be expressed through the integration of taxonomic richness at various hierarchical levels (cf. WHATLEY 1990). It can be called taxonomic diversity. For comparative purposes of animal assemblages CLARKE & WARWICK (1998) proposed a diversity index which takes the length of the path connecting two species, traced through a Linnean hierarchical classification of the full set of species in the assemblage into consideration. The index was named Average Taxonomic Distinctness (AvTD or Delta+) and measures the average length of the taxonomic path between any two randomly chosen species (*i,j*):

$$(AvTD) = Delta+ = [(\Sigma\Sigma_{i<j}\,\omega_{ij}/(s(s-1)/2)]$$

s = number of species present, ω_{ij} = taxonomic distance or distinctness weight

The AvTD can be seen as a generalisation of Simpson's diversity index (CLARKE & WARWICK 2001). This diversity index has already been used for fossil ostracods by GALOUKAS & DANIELOPOL (2004). It proved useful as an additional tool for further characterisation of ostracod assemblages characterising a stressful environment in the Late Cenozoic of Cyprus Island.

We apply here the AvTD index to data obtained during a project dealing with the description of Middle Miocene ostracod assemblages from the Vienna Basin (Hainburg, Lower Austria). Within this project, lead by one of us (W.E.P.), ostracods were studied by GROSS (2002, 2006) under various aspects, respectively systematics, biostratigraphy and palaeoecology. Ostracod assemblages have already been recognized by GROSS (2002), which differ depending on the palaeoecological situation. In the Hainburg area the influx of freshwater seems to have modulated the composition of the ostracod assemblages.

The present contribution intends to demonstrate the application of the AvTD index in order to extract additional palaeoecological information, respectively to differentiate between two areas, a predeltaic and an eumarine one.

Ostracods from 10, up to 100 m long sediment-cores were studied (in total 66 samples; 59 from Badenian, 7 from Sarmatian deposits) originating mainly from an area located close to Bad Deutsch Altenburg (Fig. 1).

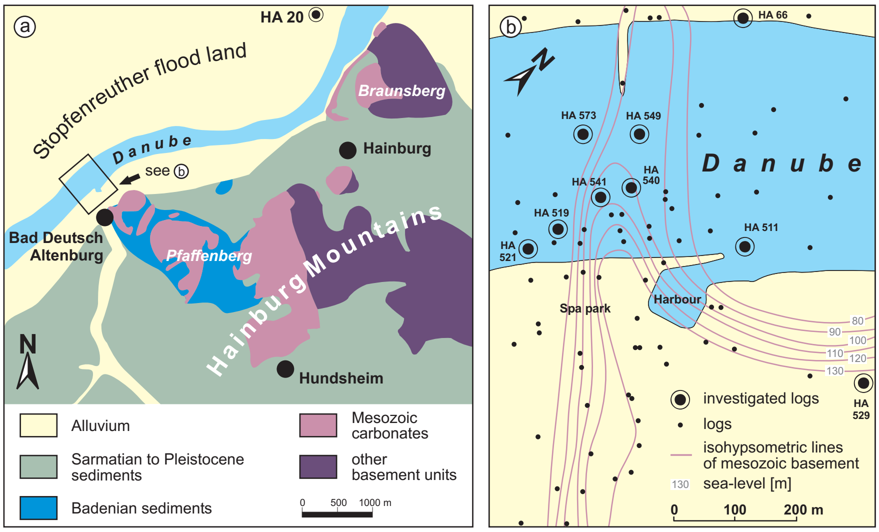

Fig. 1: Geologic map of the Hainburg area with the location of the sampling sites. a) General situation. b) Detailed map of the investigated wells.

For the present purpose the ostracods (all belong to the order Podocopida) were classified into five taxonomic units: suborder, superfamily, family, genus and species. Gross (2002, 2006) recognized 63 species belonging to: 2 suborders (Podocopa and Platycopa), 4 superfamilies (Cytheroidea, Bairdioidea, Cypridoidea, Cytherelloidea), 15 families (11 Cytheroidea, 2 Cypridoidea, 1 Bairdioidea, 1 Cytherelloidea families) and 37 genera (31 Cytheroidea, 3 Cypridoidea, 2 Bairdioidea genera and 1 Cytherelloidea genus). Note that two suborders converge in the order Podocopida.

We will discuss here only the Badenian ostracods from 16 samples belonging to seven cores containing several ostracod species as palaeoecological markers and at least four species (the lowest limit for computation of the AvTD). Respectively, we used the non-marine species belonging to the genera *Ilyocypris* (Ilyocyprididae), *Fabaeformiscandona* (Candonidae) and *Pseudolimnocythere* (Loxoconchidae), which occur in samples from boreholes labelled in Gross (2006) HA 519, HA 521, HA 540, HA 541 and HA 573 (cf. Fig. 1). A species of the genus *Fabaeformiscandona* occurs in the sample HA521/5. As the species richness of this sample is too low (cf. two species) we did not use it for computation. It should also be noted that the genus *Pseudolimnocythere* is represented by a unique species, *P. hainburgensis*, which belongs to a predominantly stygobitic group (Danielopol et al. 1991).

This species occurred only in two samples, HA 519/1 and 541/7 (Gross 2002, 2006). We did not use the latter sample in our computation because of the low number of taxa *in situ*, respectively two *Callistocythere* species.

We hypothesize that the area, called A in table 1, forms a predeltaic zone with fluctuating and lowered salinity. We use for characterisation of eumarine conditions the ostracod species belonging to the genus *Cytherella* (Cytherellidae). Representatives of cytherelloids live generally under eumarine salinity conditions (Hartmann 1989). The investigated samples (cf. Tab. 1) originate from the cores HA 20, HA 66 and HA 511. For our taxonomic diversity characterisation we eliminated the obviously drifted non-marine species belonging to the genera mentioned above from the species lists. Therefore the average taxonomic diversity was calculated using 45 species belonging to 34 genera included in 13 families, which belong to four superfamilies and two suborders (Tab. 1).

Area	Borehole Sample No.	Sub-Order	Super-Family	Family	Genus	Species	AvTD( )
A	HA 519/5	1	1	3	3	5	48.0
A	HA 519/7	1	1	4	4	4	53.33
A	HA 540/1	1	1	6	11	14	53.63
A	HA 540/3	1	1	4	5	6	57.33
A	HA 541/4	1	1	5	6	11	52.73
A	HA 541/5	1	1	4	4	5	56.0
A	HA 541/7	1	1	3	3	4	53.33
A	HA 573/19	1	2	8	16	23	54.47
B	HA 511/4	2	3	9	12	21	67.05
B	HA 511/7	2	3	8	9	15	65.71
B	HA 511/8	2	3	8	12	22	62.86
B	HA 511/9	2	3	7	11	15	65.90
B	HA 511/11	2	3	8	12	21	66.19
B	HA 66/21	2	4	9	11	14	72.97
B	HA 20/8	2	3	11	18	25	63.60
B	HA 20/9	2	3	9	19	23	63.0
	total taxa	**2**	**4**	**13**	**34**	**45**	**61.13**

Tab. 1: Taxonomic diversity of 16 ostracod assemblages from the Hainburg area (data from Gross 2006).

The results were represented graphically using the AvTD algorithm described in Clarke & Warwick (2001) and implemented in the computer programme-package PRIMER v.6 (Clarke & Gorley 2006).

The examination of the AvTD index for the eight samples of domain A showed a range of values between 48 and 57.33 (Fig. 2 and Tab. 1). One sample (HA573/19) displays a value, which lies outside the lower 95 % of the delta value simulated by randomisation of subsamples from the total species list (cf. Fig. 2 and for details of the procedure Clarke & Warwick 2001). All eight values of the A domain are located below the total AvTD value (Fig. 2). The median value for the species is 7.5, for the genera and families 4.5. Most of the species belong to one superfamily, the Cytheroidea.

The samples from the wells HA 20, HA 66, and HA 511 containing cytherelloids belong to domain B. The AvTD values vary between 62.86 and 72.97.

The sample HA66/21 lies outside the upper 95 % of the delta value simulated by randomisation of subsamples from the total species list (Fig. 2). The median value for species is 21.5, for genera 12, for families 8.5. In most cases there are three superfamilies and two suborders.

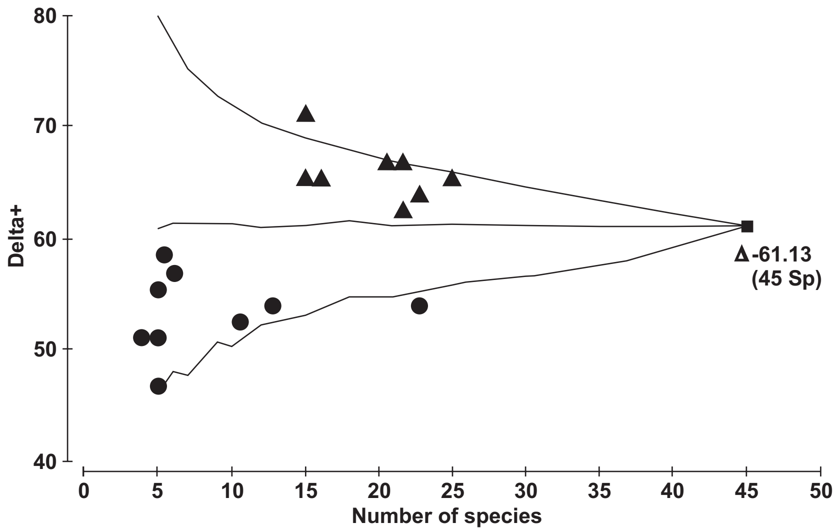

Fig. 2: Taxonomic diversity (AvTD values) of 16 ostracod assemblages from Hainburg area (dots = values for samples from domain A, triangle = samples from domain B, square = AvTD value for the total species list (cf. Tab. 1), thin line = 95 % probability funnel for the expected range of the AvTD (= delta) values.

The data presented here supplement those presented in GROSS (2002), respectively that we are dealing with two palaeoenvironmental domains – a predeltaic one and an eumarine one.

Looking at the position of the wells (cf. Fig. 1) we will note that the predeltaic zone is located on the left side and those where eumarine conditions seems to have prevailed on the right side. The taxonomic diversity of the samples from zone A is much lower than those of zone B, suggesting that the influx of freshwater into the marine system produced stressful biological conditions to the ostracods. Zone B, with a higher taxonomic diversity, suggests more stable and favourable ecological conditions as experienced by the ostracod species.

We conclude that the examination of the AvTD index represents a useful palaeoecological descriptor when combined with additional information like palaeoecological data for the selected ostracod taxa used here.

Acknowledgements
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Hydrogeological Investigations for a Sustainable Use of the Deep Groundwater Resources in the Styrian and Pannonian Basin

Gunnar DOMBERGER

General project information

The NANUTIWA-project was designed to investigate the most important aspects concerning deep groundwater systems in the Neogene sediments. The complete title of NANUTIWA is: "Hydrogeological investigations for a sustainable use of the deep groundwater resources in the Styrian and Pannonian Basin".

The content of the project was the new compilation and reinterpretation of hydrogeological and water resource data and reports with modern scientific methods. The project tasks were splitted into the work groups geology, aquifer system analyses, groundwater recharge and water resource management. The project was partly financed by the governments of Styria and Burgenland, as well as the Ministry of Life and the Ministry of Economy and Work. The total project's costs were about 1,08 million Euro. The project organisation was done by the Institute of WaterResourcesManagement of Joanneum Research. The 3 year project (2002–2006) was performed by Joanneum Research, the engineering offices Niederbacher, Meyer and Erhart-Schippek, the company Geoteam and the Technical University of Graz.

Project area

The area between the rivers Pinka and Raab and between the Eastern Alps and the border to Hungary and Slovenia forms the investigation area of the project "NANUTIWA".

Low precipitation, high evaporisation and the subsurface conditions formed the landscape and forced the inhabitants of this region to use deep groundwater systems. This was the reason why the deep groundwater exploration starts in this eastern part of Austria. From the hydrological point of view the project area of NANUTIWA covers the total catchment area of the Raab river within Austria, splitted into the counties Weiz, Hartberg, Feldbach, Fürstenfeld, Güssing, Oberwart und Jennersdorf. The eastern border of the investigation area is the border between Hungary and Austria (Fig. 1).

The project area has a dimension of 82×84 km and a total area of 4290 km^2. The central part of the investigation area, where deep groundwaters exist, covers 2870 km^2.

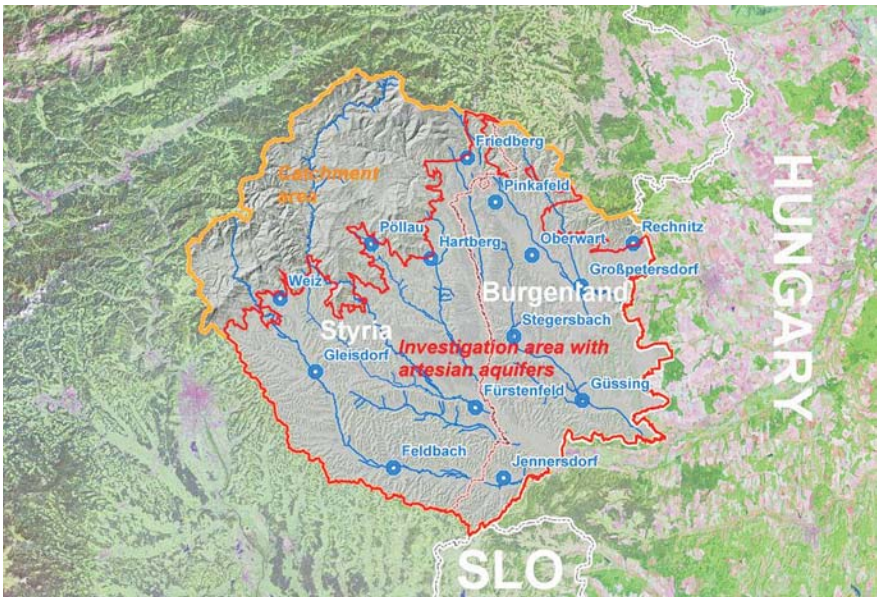

Fig. 1: Project area.

Methods and results

The database and the GIS-base, which was set up within the project, provide a decision support system and a tool to plan sustainable use of deep groundwater in the future. With this database it was also possible to visualize the geological (Fig. 2), hydrogeological and water resource relevant data and facts in a modern way. Further it was possible to calculate water production rates for each well, for each community, for each county and for the whole investigation area. The water production is splitted into production out of private free flowing artesian wells and water production out of wells, which are driven according to the real water demand.

The complexity of the geological framework enabled a successful reinterpretation of hydrogeological questions only with interdisciplinary cooperation and an intense combination of a wide spectrum of geological, hydrogeological and geophysical methods.

Deep groundwater in this area means mostly confined groundwater in a depth of about 50 up to 400 m. In those depths the deep groundwater resources are used for drink water supply. In greater depths the temperature increases and deep groundwater systems are in use as thermal waters for therapeutic and tourism purposes.

Most deep groundwaters in this region have been flowing in the subsurface for thousands of years, up to 50,000 years. This fact leads to special hydrochemical and physical conditions of the water.

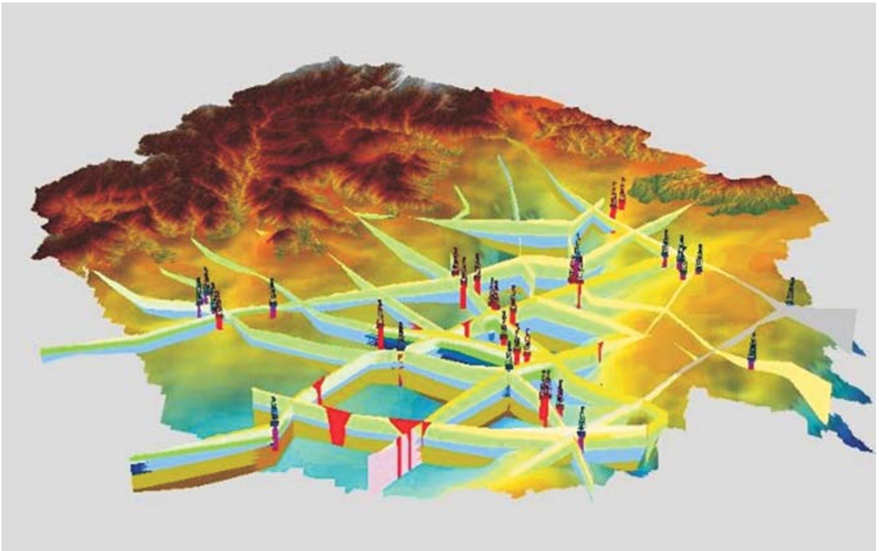

Fig. 2: Visualization of the pre-Neogene basement relief and cross sections.

These special conditions require very often water treatment to get sufficient drink water quality. These facts also include very important facts concerning water pollution and emergency water supply.

The use of deep groundwater started historically with private wells. The high and increasing number of private artesian wells led to an uncontrolled waste of deep groundwater resources of high quality. Caused by these facts, the water supply out of deep groundwater systems is getting more and more centralized and is managed by local water companies and water communities.

The NANUTIWA project provided the base and decision support system for the future use and management of the deep groundwater resources in this part of Austria.

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New Zones of Planktonic Foraminifera in the Upper Badenian and Sarmatian of the Transylvanian Basin

Sorin FILIPESCU, Lóránd SILYE & Csaba KRÉZSEK

The Middle to Late Miocene tectonic and sedimentary evolution of the Transylvanian Basin was markedly different if compared to other intra-Carpathian basins. This is well documented by the sedimentary record (locally over 2000 m of sediments) and microfossil content, mainly accumulated in deep-sea settings (KRÉZSEK & FILIPESCU 2005; KRÉZSEK & BALLY 2006). The Late Badenian to Sarmatian foraminiferal assemblages of the Transylvanian Basin were the subject of several studies during the recent decades (e.g., POPESCU 1975, 1979, 1995; KRÉZSEK & FILIPESCU 2005). However, the evolution and palaeogeographical significance of the small sized planktonic foramifera occurring around the Badenian/Sarmatian boundary and within the Sarmatian have been still studied poorly.

The small planktonic foraminifera recovered from several outcrops and wells were studied and interpreted in order to clarify their biostratigraphic potential and the relationship with the sedimentary environment.

Two distinct assemblages have to be considered in order to establish new planktonic biozones: the Tenuitellid assemblage with an acme in the uppermost Badenian and rare occurrences in the Sarmatian (mainly in the lowermost Sarmatian), and the assemblages containing *Streptochilus* in the Sarmatian. Their occurrence can improve the resolution of the Upper Badenian, show a new potential for the correlation of Sarmatian, and give clues for palaeogeographic setting of the Paratethyan basins.

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Badenian and Sarmatian from Locality Ostrovo, Northern Serbia

Vladislav Gajić, Goran Bogićević & Predrag Cvijić

The locality Ostrovo is situated in the south-eastern part of the Pannonian Basin, near the city of Pozarevac, Serbia. Investigations are based on palaeontological and petrological studies of core samples and wash residues from the six boreholes in the vicinity of Ostrovo. The presence of Badenian and Sarmatian sediments is determined by the rich association of foraminifers, ostracods, nannofossils and molluscs.

Badenian sediments are transgressive over low metamorphosed schists. Badenian sediments are represented by marine limestones of the reef complex, carbonate-terrigenous and terrigenous sediments. On the basis of rich association of foraminifera and nannofossils, Badenian sediments could be divided into Lower and Upper Badenian.

Sediments of the Lower Badenian are determined in several boreholes in the locality Ostrovo. They are mostly presented by sandstones, sandy marlstones, sandy limestones and limestones. On the basis of foraminiferal association (mostly represented with *Globigerinoides trilobus* and *Orbulina universa*, it is determined that these sediments belong to the upper part of Lagenidae Zone. Rich nannoplankton associations, which belong to nannoplankton Zone NN5 were found there (*Braarudosphaera bigelowii*, *Calcidiscus premacintyrei*, *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Helicosphaera carteri*, *Micrantholithus procerus*, *M. vesper*, *Pontosphaera multipora*, *Pyrocyclus hermosus*, *Reticulofenestra producta*, *R. pseudoumbilica*, *Sphenolithus abies*, *S. moriformis*, *Umbilicosphaera jafari*).

Sediments of the Upper Badenian are discovered in most boreholes of the locality Ostrovo. They are represented by the reef complex limestones, conglomerate sandstones and sandstones. Late Badenian age is determined by macro- and microfauna: *Turritella* sp., *Conus* sp., *Borelis melo*, *Elphidium crispum*, *E. rugosum*, *Ammonia beccarii*, *Heterolepa dutemplei*, *Neoeponides schreibersi*, *Asterigerinata planorbis*, *Valvulineria akneriana*, *Globulina gibba*, *Amphistegina* sp., *Hermanites haidingeri*, etc.

Sarmatian brackish sediments are concordant with Badenian sediments and are succeeded by Pannonian sediments. Sarmatian sediments are lithologically very similar in all boreholes. They are mostly represented by the shallow water clastic deposits, and rarely with carbonate sediments.

Grey, compact, massive conglomerates and conglomerate sandstones are determined at the base of the Sarmatian.

Upward follow greenish-grey, compact, partially decrepit, weak laminated sandstones heterogeneous in size, and rarely siltstones in intercalation with grey marlstones and claystones. Weak laminated calcareous sandstones, with macrofauna (*Cardium vindobonense*, *Modiolus incrassatus incrassatus*, etc.), and undeterminable plant remains occur in deeper levels of the boreholes.

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Shallow Gas of the Ukrainian Transcarpathian: Still Promising Exploration Frontier?

Luydmyla HAFYCH, Alexander A. KITCHKA & Oleg I. GAFYCH

The Transcarpathian Sub-basin (Fig. 1) belongs to internal depressions formed during orogenic stage of the Carpathian belt evolution and stretches along its ranges (KRUPSKY 2001). It borders on the Pannonian Basin (Alföld) in the south. The Beregovo fault zones separate it from the Pannonian Basin, which enters into Ukrainian territory with small patches. The sub-basin consists of pre-Neogene basement and Neogene sedimentary fill. The basement (Paleozoic, Mesozoic and Paleogene) is poorly studied. However, it is possible to speak of its heterogeneous fault-and-fold structure inherited from the Tatra-Veporides. In the NE it is overlain with angle and stratigraphic unconformity by wide stripe (15–18 km) of the Central Carpathian Paleogene flysch. Neogene molasses covering the basement rocks build the upper structural stage. Less deformed Neogene rocks, from Karpatian sandstones to sandy-clayey series of Pleistocene fill deep troughs and form anticline crest lines, dissected by the system of along-terrain and transversal faults.

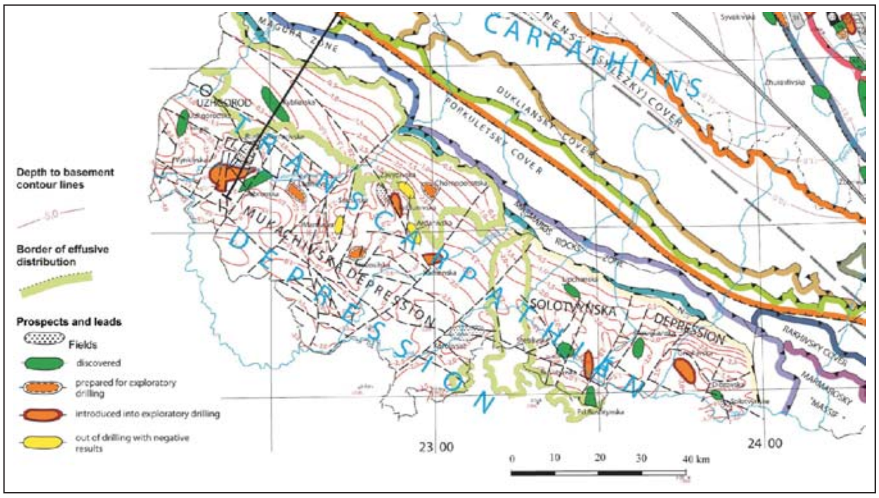

Fig 1: Tectonic map of the Transcarpathian Sub-basin (cf. KOLODIY 2004).

Faults in the Neogene cover mimic the strike and sense of main tectonic surfaces in the pre-Neogene bedrock. These faults have amplitudes of 500–700 m in the central part of the sub-basin and up to 1000–1400 m in the Beregovo zone.

The Transcarpathian gas-prone Sub-basin includes the Mukachevo, Solotvino, and East Slovak depressions, and Maramures Sub-basin. The former two ones are located in Ukraine. Sedimentary section is mainly represented by Badenian stage with thick evaporites and manifestation of halokinesis in the Solotvino depression. As to the Mukachevo one the most typical are younger sediments of Sarmatian, Pannonian and Levantian age accompanied with rather powerful magmatism (Kolodiy 2004). Hydrocarbon production comes from Badenian, Sarmatian and Pannonian. In the Ukrainian part, gas pools are found in the depths from 300 to 1750 m. Productive intervals are mainly composed by rhythmic alternation of sandstones, sands, shales, clays, siltstones and tuffaceous rocks with salt rocks at the level of Middle Badenian. The reservoirs in the Solotvino depression are represented by Lower Badenian rocks with porosity of 5–12 %, and permeability up to 0.27×10^{-3} mkm^2. Reservoirs in the Mukachevo depression are Upper Badenian, Sarmatian and Pannonian sandstones of 10–22 % porosity and permeability varying from 0.12 to 125–174, sometimes up to 500×10^{-3} mkm^2. Reservoir properties are very variable in space and often have a lenticular nature. Seal rocks are evaporites of Tereblia suite (above Novoselitsia tuffs in the Solotvino depression) and clayey units of Upper Badenian, Sarmatian and Pannonian in the Mukachevo depression).

Discovered gas fields are usually attributed to faulted brachianticlines. Productivity contours are controlled by structural, sedimentological and tectonic factors. The depth to GWC can vary by hundred metres within the same field. Typically, here is anticlininal, combination, at tectonically screened pools. A particular feature of gas fields in the Mukachevo depression (like for Slovak ones) is their high hydrocarbon column along with minor reserves. Transcarpathian natural gases consist of methane and nitrogen. Generation capabilities for hydrocarbons in the Transcarpathian Basin are primarily linked to the Miocene, especially to clay series of the middle (Lower Tereblia sub-suite) and the lower part of Upper Badenian rocks (Solotvino suite). One cannot exclude the Karpatian rocks as source rocks as well. The source of hydrocarbons could also be located in the folded bedrock (e. g.,, Triassic dark-grey limestones and marls, Jurassic, Cretaceous and Paleogene dark shales) with high organic matter content.

The formation pressure in the Mukachevo and Solotvino depressions is close to the hydrostatic one and sometimes exceeds it by 5–20 %. The Transcarpathian region is characterized by anomalous thermal regime. The average geothermal gradient is 4.4 °C/100 m, however, in some location it is even higher. For example, the well Mukachevo-1 revealed 200 °C in the depth of 4200 m, and in the well Komarivtsi-1 195 °C in 4000 m depth. Here the geothermal gradient varies from 5 to 6 °C/100 m up to the depth of 2000 m. A lower gradient is fixed for the Solotvino depression – 3.7–4.2 °C/ 100 m.

There are 12 commercial discoveries taken into consideration both Ukrainian and East Slovak parts of the Transcarpathian Sub-basin: one oil-and-gas (Pozdisovce), four gas condensate (Banovce, Lastomir, Stretava, Ptruksa) and seven gas (Trgoviste, Pavlovice, Terebisov in Slovak Republic; Rusko-Komarivske, Stanivske, Korolivske and Solotvinske in Ukraine) fields. Eight of them are located in the East Slovak depression, three in Mukachevo and one in Solotvino depressions. The first Ukrainian discovery – Solotvinske – was made in 1982. Gas is trapped in the salt plug anticline. The pay zone in Badenian of the well no. 1 at 1440–1530 m produced 137 MMcm/d of gas. Main reservoir varieties are represented by fractured tuffs and tuffites with porosity of 6–13 %. Production contains 95.6 % of methane and 3.4 % of its higher homologues. Formation pressure is 14.73 MPa at 1485 m. Rusko-Komarivske field was discovered in 1985 and controlled by drape fold over gabbro-diabase-basalt intrusion into Badenian sequence. The field consists of 7 individual pools in the Sarmatian sandstones of 14–18 % porosity. Initial flow rates varied from 17–75 MMcm/d in the depth of 900–1650 m. Gas is mainly methane (60–73 %) and nitrogen (25–33 %). Korolivske gas field was discovered in 1988 and its exploration has not been finished yet. Well no. 2 produced 150 MMcm/d flow rate of gas (interval 710–740 m) from Pannonian sandstones of 12–14 % porosity. The field is the anticline structure of 10 × 4 km in size consisting of two domal crests separated by the saddle. The western cupola is not explored. Gas contains 60.2 % of methane, 3.1 % of its higher homologues, nitrogen (26.6 %), and of carbon dioxide (10.6 %). The latest discovery of Stanivske field was made in 1990. The trap is formed by faulted brachianticline with unconformable relationship between Badenian and Sarmatian bedding planes. The field is under exploration. Yablunivka-2 well produced 115 and 15.3 MMcm/d flow rates of gas from two pay zones, from 310–390 m and 192–238 m respectively. Reservoirs are sandstones of 10–18 % porosity containing mainly 95 % of methane (Hafych & Kurovets 2004). During all history of hydrocarbon exploration in Ukraine the Transcarpathian gas-prone sub-basin was a second order priority. Therefore its resource potential estimated at 140 MMtoe is speaks of under-explored and immature province. The analysis (Tab. 1) of the Ukrainian part of the Transcarpathian Sub-basin testifies that probable reserves (over 130 MMtoe) take the lion share of the resource potential.

Proven reserves of 4 discovered gas fields in the Ukrainian part (2.7 Bcm) are only 3 % from the whole resource potential of the region. Plus, it is known that exploratory drilling in the Transcarpathian Sub-basin has revealed several prospective leads requiring further analysis, exploration and development.

From the figures follow that rather equal shares 70.3 and 62.2 MMtoe is distributed between Neogene fill and pre-Neogene structural stage, respectively. As to the Neogene plays proper around 30 MMtoe are referred to Sarmatian and Pannonian sediments in depths of 0.5–1.5 km.

Main exploration activity in the Ukrainian Transcarpathian region took place during the 80's of the last century. In this time the primary attention was paid to search for big hydrocarbon accumulations and deep drilling into the folded basement.

Productive complexes	Probable reserves, Category D_1	Probable reserves, Category D_2	Probable reserves, recoverable	Prospective area, 1000 sq.km	Density of reserves, Mtoe/sq.km^2
T (Triassic)		15.6	13.3	2.9	5.4
K (Cretaceous)		12.4	10.5	1.0	12.4
P (Paleogene)		18.6	15.8	1.4	13.3
N_1krp (Karpatian)		15.5	13.2	1.6	9.7
N_1b (Badenian)	36.1		31.0	4.9	7.6
N_1s (Sarmatian)	28.6		24.2	4.0	8.5
$N_{1\text{-}2}$pn (Pannonian)	5.6		4.7	0.8	7.7
TOTAL	70.3	62.1	112.7		

Tab. 1: Distribution of initial gas reserves in the Transcarpathian petroleum-prone province (remaining potential), Bcm.

Seismic works were targeted to map large structural traps. During the break-up of the USSR and the pioneering years of Ukraine's independence the exploration works were conducted only episodically and seismic surveying was almost stopped.

Thus, the present-day seismic and geological database for the region is still inadequate to conduct successful exploration. Consequently, we face the following problems:

— Insufficient knowledge on detailed structure of pre-Neogene basement;
— Lack of firm and continuous reflectors in the Neogene sequence;
— Poor quality of the prospects and leads bear high exploration risk;
— Potential traps of stratigraphic type did not studied or studied unsatisfactory;
— The resource potential of shallow gas (up to the depths of 0.5–1.0 km) is poorly recognized due to the orientation on deep horizons and well design.

As a consequence, further exploration strategy should take into account the peculiarities of the known geological structure and hydrocarbon potential of the basin following from the experience gained during previous period and get concentrated onto such trends as:

— Shallow gas prospects in the Neogene sedimentary cover;
— Gas prospecting in the anticline traps of the folded pre-Neogene basement;
— Exploration in the fractured volcanic and volcaniclastic rocks.

Serious economic advantage of the area is a possibility to use abandoned wells drilled to the pre-Neogene basement as hot water producers to utilize hydrothermal energy and conversion of depleted fields into gas storages on the way of Russian gas to the West.

Abovementioned testifies that hydrocarbon potential of the Transcarpathian Basin is far from exhausting and here there chances to discover new fields. Shallow depths of productive complexes and existence of pipeline infrastructure make the development of hydrocarbon potential of the Ukrainian Transcarpathian economically viable despite of minor proven reserves.

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The Neogene Freshwater Crabs of Europe

Sebastian KLAUS & Martin GROSS

Freshwater crabs represent one of the most diverse groups of brachyuran crustaceans. Although several studies on recent material use palaeontological data to reconstruct their phylogeny and palaeobiogeography (e.g., DANIELS et al. 2006, KLAUS et al. 2006), the freshwater crab's record remains poorly known. Most of their fossil relatives come from Neogene sediments of the North-Alpine Foreland Basin and the rim of the Central Paratethys.

We recorded all taxonomic data of the fossil freshwater crabs of the European Neogene and recognize seven species that we assign to the genus *Potamon*: *Potamon quenstedti* (Engelswies, Langenenslingen; Karpatian), *Potamon speciosus* (Öhningen; Upper Badenian to Lower Sarmatian), *Potamon hungaricum* (Ždana; Lower Sarmatian), *Potamon proavitum* (Andritz/Graz, St. Stefan/Gratkorn; Upper Sarmatian), *Potamon* n. sp. (Höwenegg; Pannonian), *Potamon castellinense* (Castellina marittima; Upper Miocene), *Potamon antiquum* (Dunaalmás, Süttö, Mogyorós, Bajót; Upper Pliocene/Lower Quaternary).

Today, two families of freshwater crabs occur in the Mediterranean region: the Potamidae and the African Potamonautidae in the Nile valley. Several of the European fossil freshwater crabs were formerly assigned to the Potamonautidae (e.g., BOTT 1955). The only morphological character that could support this is the typical straight and sharp postfrontal crest of potamonautids. In contrast, all known fossil freshwater crabs of Europe show the potamid character state with a postfrontal crest forming two distinct lobes. This argues for a closer relationship with the Potamidae. Therefore we contradict former assumptions on a closer relationship with African or Southeast Asian freshwater crabs and argue for the fossil crabs to be part of the stem-group of the modern European potamids.

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Mineralogical and Geochemical Characteristics and Provenance of Upper Miocene Sediments in the South-western Part of the Pannonian Basin

Marijan Kovačić & Anita Grizelj

Upper Miocene sediments of the south-western part of the Pannonian Basin have been investigated in the region of Hrvatsko Zagorje, Mt. Medvednica and Mt. Žumberak (Fig. 1). They consist of various siliciclastic and carbonate rocks that are grouped into six informal lithostratigraphic units: Croatica, Medvedski Breg, Ozalj, Andraševec, Hum Zabočki and Pluska (Kovačić & Grizelj 2006).

The Croatica unit consists of thin-bedded clayey limestones and marls with rare intervals of massive marls and sands. The Medvedski Breg unit consists mainly of massive marls with rare occurrences of sand-gravel deposits. Middle- to coarse-grained clastic sediments are typical for the Ozalj unit. An alternation of sand beds, silts and silty marls is characteristic of the Andraševec unit, while the Hum Zabočki unit consists of an alternation of sand beds and silts. The Pluska unit, the youngest unit, which has been doubtfully referred to the Miocene, consists of clay, silt and sands with layers and lenses of gravel and coal.

Mineralogical and chemical composition of the detritus indicates clearly its origin from two different source areas.

The clastic detritus of the older units (Croatica, Ozalj and Medvedski Breg) is immature, originating from intense mechanical weathering of the hinterland and islands. Their composition varies greatly and reflects clearly the composition of the source rocks.

Pelitic sediments of Medvedski Breg and Andraševec units are classified as marls or silty marls. They are composed dominantly of calcite and clay minerals, while quartz and feldspars are less abundant. Among clay minerals, in the $<2\mu$m insoluble residue fraction, smectite, illite, chlorite and kaolinite were determined Grizelj et al. (in press). Observed gradual decrease in carbonate content, and simultaneous increase of clayey-silty component, going from Medvedski Breg to Andraševec unit, is the result of the gradual increase of terrigenous influence.

Younger units (Andraševec, Hum Zabočki and Pluska) are composed of mineralogically and texturally relatively mature sandy and silty detritus.

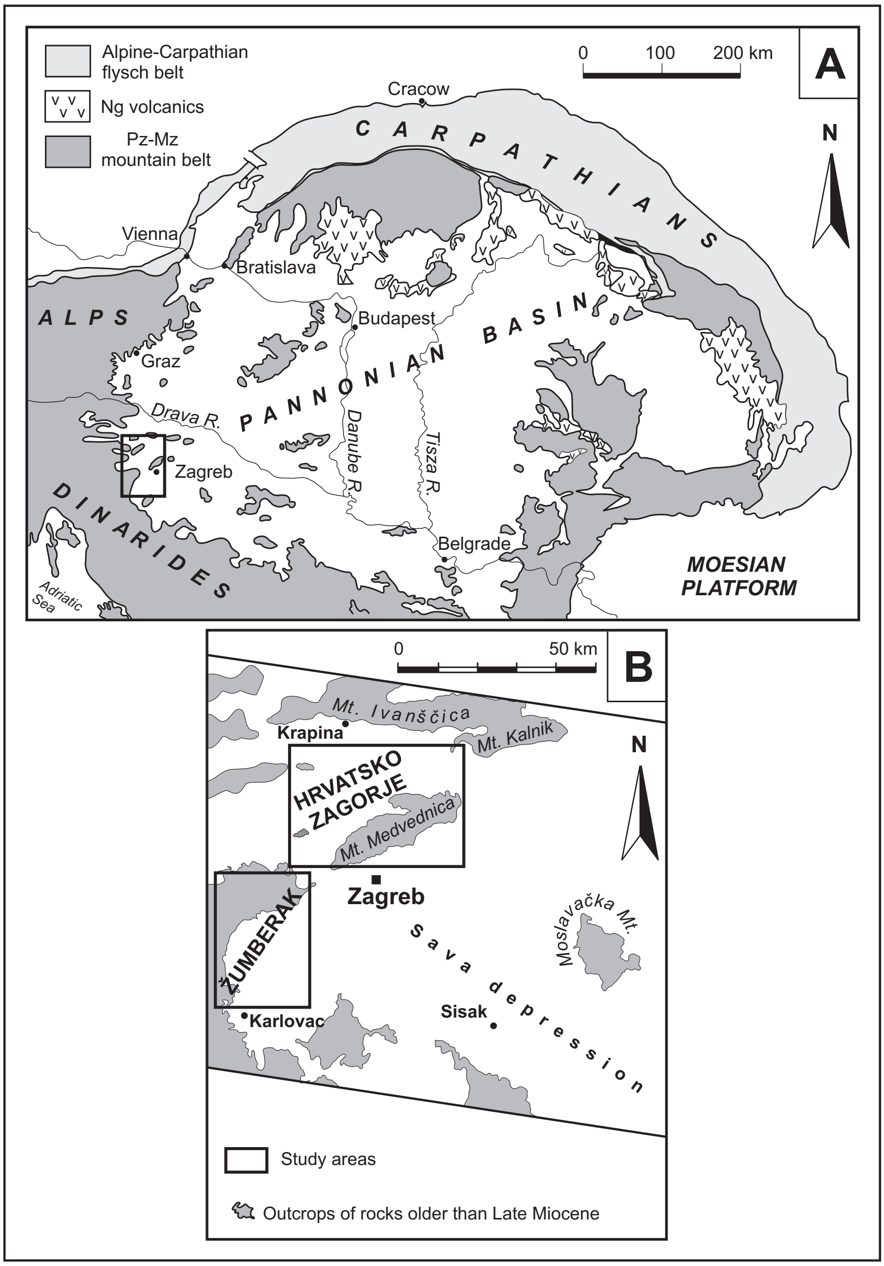

Fig 1: A) Sketch of the Pannonian Basin and its surroundings. B) Location of the study areas.

The detritus has a uniform composition in the entire study area. It derived from weathering of various sources, mainly siliciclastic sediments and metamorphic rocks, and to a lesser degree, basic and ultrabasic magmatic rocks (Kovačić & Grizelj 2006). The composition of the main detrital modes of the arenites, palaeotransport measurements and mineralogical and chemical composition of pelitic sediments suggest their provenance from an orogenic belt located to the NW, W and NE of the studied area, i.e., the Eastern Alps and Carpathians (Fig. 2).

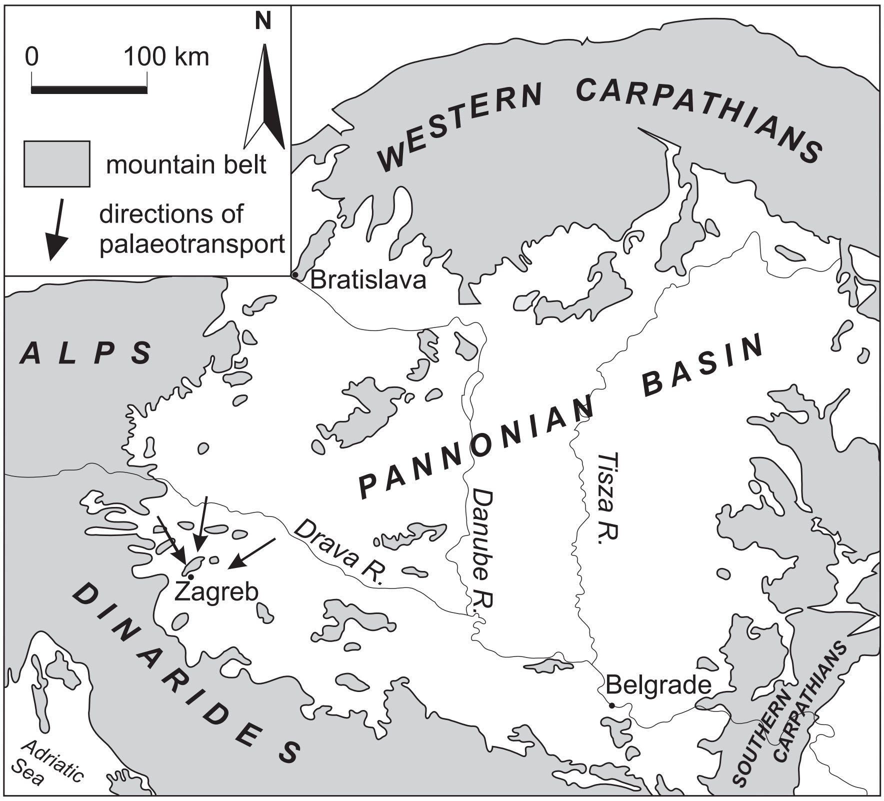

Fig. 2: Dominant directions of progradation of Upper Miocene clastic detritus of the Andraševec and Hum Zabočki units in the SW Pannonian Basin (modified after Kovačić & Grizelj 2006).

A gradual change of the heavy mineral assemblage was observed at the contact between Upper Miocene and Pliocene deposits. This change could be linked to the structural changes in the Alpine-Carpathian orogene when rocks from deeper parts were brought to the surface, or to the rearrangement of source areas within the orogene area.

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Fauna of a Large Early Middle Miocene Lake of Serbia

Nadežda KRSTIĆ, Slobodan KNEŽEVIĆ & Sanja PAVIĆ

At the beginning of the Middle Miocene the Vardar Composite Terrane sunk together with Serbian-Macedonian CT, giving the room for creation of a large lacustrine system. The type of sediment and fauna indicate a single lacustrine system. This large basin (Fig. 1) was filled by nearly freshwater during the Lower Badenian. At the beginning of the Middle Badenian, the connection with the marine realm was established and the lake turned into a gulf. The name Serbian Lake was introduced by KRSTIĆ & KOMARNICKI (1996).

The lacustrine part of the sedimentation cycle, lying conformably below the Middle Badenian, belongs to the Lower Badenian. On the basis of fossil macroflora (PANTIĆ 1962), molluscs (STEVANOVIĆ 1977; KNEŽEVIĆ 1996) and vertebrates (PETRONIJEVIĆ 1967; PAVLOVIĆ 1981) the age of the marl was determined as Middle Miocene – equivalents of the Badenian (STEVANOVIĆ 1977). Based on the fossil flora it was placed into the “Helvetian”. The age of the Kragujevac Neogene was determined as “Tortonian” (GAGIĆ 1972). Well before this PAVLOVIĆ (1901) concludes that “Melanopsis Marl and the related strata […] are older than it was previously considered, its age is the Miocene and […], they are equivalents of the Second Mediterranean stage”, the Badenian.

The malacological investigation started with the determination of BRUSINA (1894, 1902: *Ancylus serbicus*, *A. dimici*, *Planorbis pavlovici*, *Prososthenia serbica*) and PAVLOVIĆ (1903: *Prososthenia fuchsi*, *Melanopsis petkovici* and others). Still we are not far from its initial phase in spite of excellent monograph of V. MILOŠEVIĆ (unpubl.) dealing with the Peć surroundings, a branch of Serbian Lake containing PAVLOVIĆ’s (1933) species *Hydrobia santrici*, *Bythinella cvijici*, *Micromelania proni*, *M. metohiana*, *Kosovia praepontica*, *Gyraulus decani*. STEVANOVIĆ (1985) determined to the north of it *Radix cobeltiformis*, *R. levasi*, *Fossarulus praeponticus*, *Marticia macarii*. Investigation of KNEŽEVIĆ (1982, 1991) completed the picture enlarging the areas of some species, being connected to different facies – with *Congeria nisseana*, *C. cvitanovici servica*, *C. antecroatica sumadica*, *Kosovia matejici*, *Micromelania proni* and many more. Anyhow, there are many of unsolved taxonomic questions.

There is not much investigation on ostracode meiofauna. New species of the freshwater genera have been described from different localities. Single monospecific association is the one of *Amplocypris snegotini*.

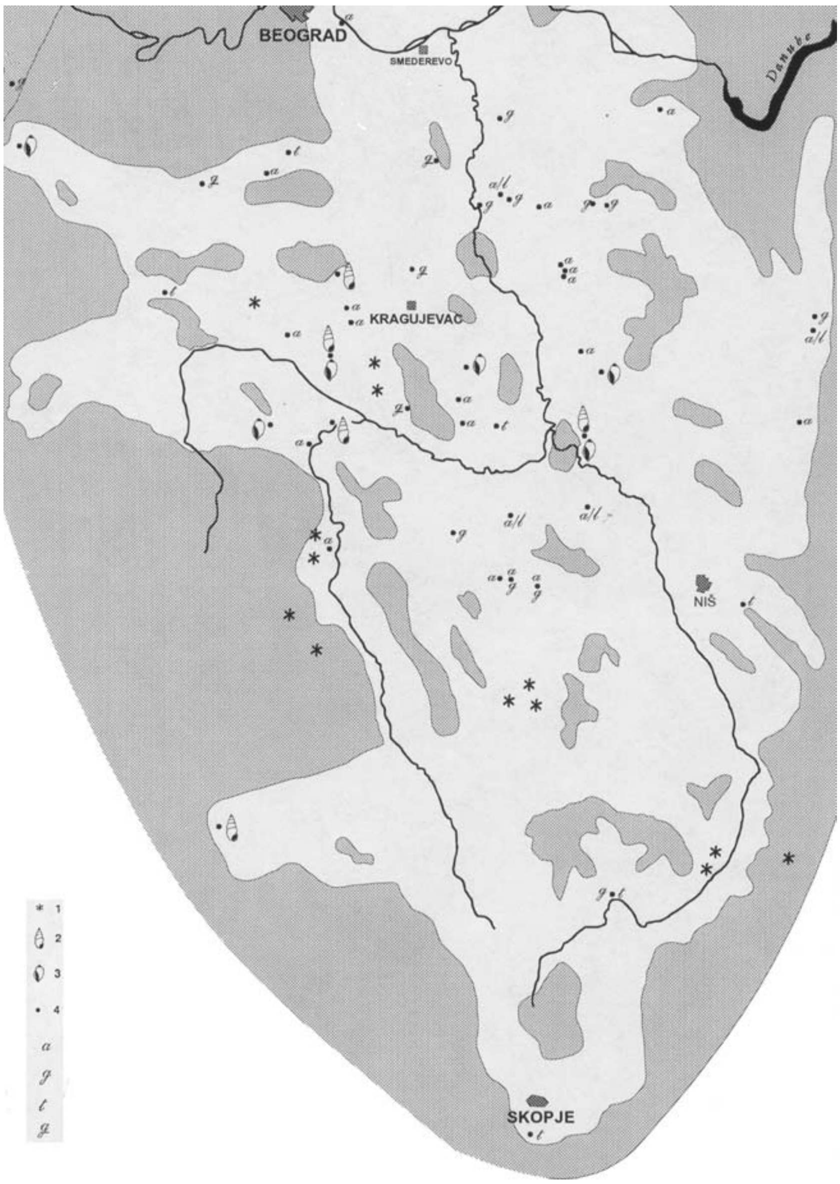

Fig. 1: Extend of the Serbian Lake in Serbia and northern Macedonia (without SW Bulgaria prolongation). Legend: 1) Contemporary volcanoes. 2) *Prososthenia* sites. 3) *Kosovia* sites. 4) Proboscidean sites: *g - Deinotherium giganteum*, *a - Anancus arvernensis, a/l - Mastodon angustidens/longirostris*, *t - Zygolophodon turicensis.*

The community from sandy facies of Donja Mutnica contains large *Candona bouei*, *Herpetocypris miocenica,* smaller *Ilyocypris pannonica*, *Candona mutnicae*, *Pseudocandona miocenica*, *Dinarocythere costata* and small *Potamocypris bouei* and *Cypridopsis pannonica* species (Krstić 1972). The last one was determined as "*Cheikella*" by Gagić (1972) due to smaller and larger hump on some specimens. Few species from marly sediments *Ohrididela sabante*, *"Reticulacandona" baljkovacensis* (Krstić 1974) are widespread. The species *Mediocypris nisseana* extends from Belgrade to Niš. Mentioned new species has been repeatedly spotted recently. There is a tight relation, geological and geographical, between all the quoted localities and they are of the same age. Same meiofauna of such type has also been collected later (Krstić et al. 1997).

Proboscidean remnants are most widespread along the whole realm of Serbian Lake. Maybe because they are large enough and curiously shaped to be noticed as important. There are remnants of following species: *Deinotherium giganteum*, transition of *Mastodon angustidens* toward *M. longirostris*, *Anancus arvernensis* and *Zygolophodon turicensis*. Mastodonts of Serbia were revided by Pavlović (1981).

Conclusion: The main molluscs in the Serbian Lake are *Congeria*, *Kosovia* and ornamented *Prososthenia* indicating some salinity of the lacustrine water. Only *Kosovia* is not found yet in the eastern parts of the Lake. The same is valid for the ostracode genera *Mediocypris* and *Dinarocythere*, which are absent from eastern parts of the lake. Does it mean that the water was less saline there? Or is the reason that the upper parts of lacustrine column, bearing autochthonous fossils, were washed of? Most of collected proboscideans indicate a younger age, especially *D. giganteum*, but its ancestor *D.* aff. *giganteum* appeared earlier, together with *A. arvernensis* and *M. angustidens/ longirostris*. There is need of the micro-mammal study in sites with proboscideans.

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Terminal Miocene Events in the Pannonian Basin

Imre MAGYAR & Orsolya SZTANÓ

The Late Miocene Messinian age has witnessed profound palaeogeographic re-arrangements both in the Mediterranean and in the Paratethyan realms (POPOV et al. 2006). These included the Messinian salinity crisis, commonly interpreted as a complete desiccation of the Mediterranean Basin (HSÜ et al. 1977), and at least a significant base-level drop, if not total desiccation, of the Black Sea and Dacian Basins (HSÜ & GIOVANOLI 1979; CLAUZON et al. 2005; GILLET et al. 2006). Another common feature shared by the two realms is the sudden appearance of a characteristic brackish water fauna in the post-salinity crisis "lagomare" of the Mediterranean (ESU 2007) and at the beginning of the Pontian age in the Eastern Paratethys (NEVESSKAJA et al. 1987).

How did these events affect the Central Paratethyan Pannonian Basin? Many authors argued that the Pannonian Basin became part of a united Paratethys at the beginning of the Pontian, and that Eastern Paratethyan Pontian fauna, first of all cardiid bivalves, entered and conquered the basin at that time (NEVESSKAJA et al. 2001). Study of seismic reflection profiles led some authors to argue that the Pannonian Basin experienced a large-scale (several hundred metre) base-level drop at about the time of the Messinian salinity crisis (CSATÓ 1993). According to this view, the Pannonian Basin shared the history of the Eastern Paratethys: it received a new mollusc fauna immigrating from an adjacent basin at the beginning of the Pontian, and experienced significant lowering of water level during the late Messinian salinity crisis.

Several lines of evidence, however, indicate that this might not be the correct interpretation of the palaeontological and seismic record. In fact, all early Pontian cardiid genera of the Black Sea Basin, with the single exception of *Eupatorina*, have a long stratigraphic record well back into the Tortonian within the Pannonian Basin. The first representatives of *Euxinicardium*, *Pseudocatillus*, and *Paradacna* appear before 9.5 Ma in the deposits of Lake Pannon. *Prosodacnomya* originated from the "*Lymnocardium*" *decorum* group around 8 million years ago (MÜLLER & MAGYAR 1992). The first known representative of *Pontalmyra*, *P. budmani*, is also at least as old as 8 Ma. "*Euxinicardium*" *subodessae* of the Black Sea Basin corresponds to "*Euxinicardium*" *ochetophorum* of the Pannonian Basin, the latter originating from "*Lymnocardium*" *vicinum* sometime between 8 and 7 Ma. During most of the Tortonian age, Lake Pannon was the only waterbody inhabited by endemic brackish lacustrine cardiids (subfamily Lymnocardiinae).

Thus it seems very probable that the "alien" bivalve fauna that appeared at the beginning of the Pontian in the Euxinian Basin came from Lake Pannon. The stratigraphic data seem to support the following migration routes for Lymnocardiinae: Lake Pannon (Tortonian) > Euxinian Basin (Early Pontian) > Aegean Basin (Late Messinian) > Mediterranean (latest Messinian, "lagomare").

Our regional seismic studies, including 3D volumes, in the north-eastern shelf of Lake Pannon revealed that seismic onlaps on the shelf-margin clinoforms, interpreted earlier as representing a significant sequence boundary, were in fact caused by strike variability of the sediment supply. Reconstruction of the post- and partly synsedimentary deformation history of the basin fill indicated that the apparent difference in water depth below and above the boundary is only virtual, thus the onlaps do not necessarily justify regional lake-level drops. The only regionally extended unconformity within the late Miocene to Pliocene succession of the Pannonian Basin, however, can be traced along the entire length of the northern shelf of the basin. This unconformity always separates deltaic sediments of Lake Pannon, sometimes with obviously eroded surface, from onlapping fluvial to paludal deposits with characteristic Pliocene fossils. Towards the basin proper the unconformity becomes a conformable surface, whereas in the margins it is usually strongly tilted basinwards, arguing for tectonic origin. Where dated, it is older than 4.6 Ma and younger than 6.8 Ma (Pogácsás et al. 1994).

These features indicate that Lake Pannon remained isolated throughout the Messinian. Although its water level was not directly influenced by the drawdown of the Mediterranean and the Eastern Paratethys, this lake was the source of the Pontian and, partly and indirectly, of the lagomare fauna. The major unconformity in the basin is a consequence of a tectonic inversion (Horváth & Cloetingh 1996; Sacchi et al. 1999) that began sometime in the latest Miocene or earliest Pliocene.

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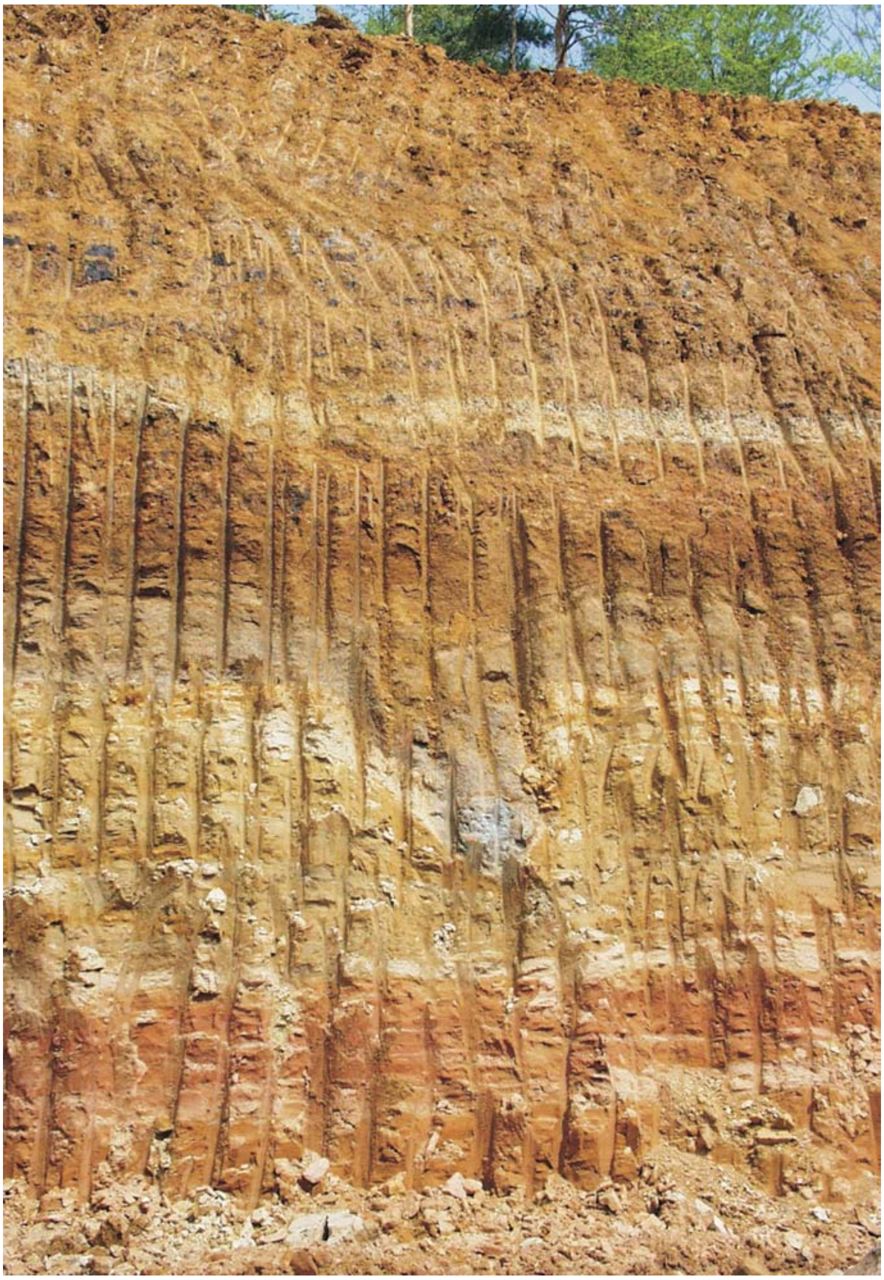

Quarry Klöch (bomb-sag structure; photo: H. Polić).

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Pectinid Bivalve Zonation of the Central Paratethys

Oleg MANDIC

The study provides a work out proposal for a new Central Paratethys pectinid bivalve zonation defining 12 biozones within a time span between the Lower Oligocene "Solenovian" crisis and the Mid-Miocene Sarmatian restriction event. The period covers about 17 Ma.

Pectinid bivalves restricted to the fully marine environments got extinct in the region following the latter event. Otherwise the "Solenovian" crisis signalized the early installation of the Paratethys as an independent realm positioned northwards and northeastwards from the Mediterranean Tethys region. Pectinid bivalve record of the Paratethys is forced mainly by the immigrations from the Tethys although with the Lower Miocene *Oopecten rotundatus–Oopecten gigas* lineage an example for the autochthonous evolution is represented as well. Except for three Taxon Range Zones (TRZ) all other zones are Interval Zones (IZ) defined between the first occurrences of name bearing taxons. Bounded to shallow marine environments and the basal parts of transgressive sequences, the zonal boundaries correlate roughly to Central Paratethys stage and substage boundaries. The calibration of Badenian zones is underpinned by the type strata, regional benthic foraminifera zonation, planktonic foraminifera marker and the corresponding calcareous nannoplankton biozones.

The here proposed Central Paratethys pectinid bivalve biozones are as follows:

1. *Costellamussiopecten deletus–C. pasini* IZ, top of the "Solenovian event", top of the Kiscellian.
2. *Costellamussiopecten pasini–O. rotundatus* IZ, Lower Egerian.
3. *Oopecten rotundatus* T.R.Z, Upper Egerian.
4. *Oopecten gigas* TRZ, Lower Eggenburgian.
5. *Flexopecten palmatus–F. hermansseni* IZ, Upper Eggenburgian.
6. *Flabellipecten hermansseni–Pecten fotensis* IZ, Ottnangian.
7. *Pecten fotensis–Pecten revolutus* IZ, Lower Karpatian.
8. *Pecten revolutus–Gigantopecten nodosiformis* IZ, Upper Karpatian.
9. *Gigantopecten nodosiformis–A. malvinae* IZ, lowermost Badenian ("Styrian Level", *Praeorbulina* Occurrence, NN4).

10. *Aequipecten malvinae–Aequipecten elegans* IZ, (“Grund Level”, Lower Lagenidae Zone, *Praeorbulina–Orbulina* Co-occurrence, NN5).
11. *Aequipecten elegans–Delectopecten bittneri* IZ, (Upper Lagenidae Zone, *Orbulina* Occurrence, NN5).
12. *Delectopecten bittneri* TRZ, Upper Badenian (*Velapertina* Occurrence, NN6).

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Dinaride Lake System vs. Lake Pannon – The Mollusc Perspective

Oleg MANDIC & Mathias HARZHAUSER

The Dinaride Lake System (DLS) was a long-lived, lacustrine-continental environment, which was established during the Miocene along the Dinaric Land on a palaeogeographic barrier between the Paratethys and the proto-Mediterranean seas. Today, the sites bearing these faunas are distributed along the territories of Croatia and Bosnia and Herzegovina in SE Europe.

Extensive literature and collection works have been carried out to obtain the species level diversity of the DLS fauna. That affords, including the taxonomic revision and palaeoecological and palaeobiological interpretations of the assemblages, revealed 190 species level taxa grouped into 36 genera. Among these, the most diverse genera are prososthenid (*Prososthenia*) and melanopsid (*Melanopsis*) gastropods, followed by dreissenid bivalves (*Mytilopsis*). Each of these groups comprises more than 30 species and subspecies.

90 % of the species are endemics, which result from an autochthonous evolution within the DLS. The species richness and the dominance of *Mytilopsis* and *Melanopsis* suggest palaeoenvironmental conditions comparable with those of the neighboring, Late Miocene, long-lived Lake Pannon (LP), which displays a similar metacommunity structure during its early phase. The coinciding palaeoenvironmental conditions are also indicated by a spectacular development of “morpho-pairs” (e. g., spitting image patelloid morphologies of the endemic snails *Clivunella* in DLS and *Valenciennius* in LP, which both evolved independently from different freshwater dwelling ancestors).

Although the morphospace analysis suggests similar evolutionary trends in both lacustrine systems, there is almost no sympatry on the species level. Based on the regional geologic and stratigraphic evidence and the partial (stratigraphical) superposition of two lacustrine systems at the southern margin of the Pannonian Basin System, the initial radiation of the DLS molluscs precede the one of the LP by, at least, 5 Ma. Conspicuously, the presence of genera such as the peculiar planorbid snail *Orygoceras*, being endemic to DLS and LP, implies on the other hand some faunistic relation between those lake systems.

Conclusively, the DLS deposits bear the evidence on an exceptional Miocene autochthonous radiation and speciation well comparable to the much better known one of the adjoining Lake Pannon. The study suggests the time-delayed evolutionary sequences evolving under similar regulative palaeoenvironmetal conditions.

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Correlation of Miocene Volcanics in the Area of the North Hungarian Paleogene Basin by the Combination of Palaeomagnetic Marker Horizons and Magnetic Polarities

Emö Márton

There have been several waves of palaeomagnetic investigations in the Neogene volcanic areas of the Pannonian Basin (e.g., Márton & Márton 1968, 1969; Dagley & Ade-Hall 1970; Nairn et al. 1971; Andó et al. 1977; Balla & Márton 1978) aiming at dating and correlating volcanic rocks by magnetic polarities and at obtaining palaeomagnetic pole positions. The latter were based on selected site mean palaeomagnetic directions and the directions departing from the cluster of these were regarded as outliers. In these studies volcanoclastics were not included.

In the late 1980s, the Miocene ignimbrites of the Salgótarján Basin and of the southern Bükk foreland became the most interesting subjects for palaeomagnetic research in Hungary. The results were primarily of geodynamic significance, since they indicated large-scale tectonic rotations (Márton & Márton 1996) taking place in the intervals of 18.5–17.5 Ma and 16.0–14.5 Ma, respectively (Márton & Pécskay 1998). However, it was soon realized that the rotation events offered a new tool for stratigraphic correlation. The idea was that palaeomagnetic marker horizons (a one-way pattern of declination change) combined with traditional magnetostratigraphy could make age estimation and correlation highly reliable.

The palaeomagnetic marker horizons in the study area (comprising the volcanic areas named in Fig. 1) divide the Tertiary sequence into three parts. The oldest is a Late Eocene–Early Miocene segment, which ends with the lower (rhyolite) tuff, at about 18.5 Ma, and is characterized by 80° counter-clockwise rotated declination (N1–R1, Fig. 1). The segment between 17.5 and 16.0 Ma, shows 30° counter-clockwise rotated declination (N2–R2) and ends with the middle (dacite) tuff. Finally, the segment younger than 14.5 Ma includes the upper (rhyolite) tuff and exhibits about 10° clockwise rotated declination (N3–R3). The differences in declinations (induced by tectonic rotations) are so large that other mechanisms, which cause scatter also in the declinations of fast cooling igneous bodies can not weaken the correlation power of the marker horizons.

As a result of systematic palaeomagnetic investigation, the chronostratigraphic position of the volcanoclastics of the North Hungarian Paleogene Basin got known at more than one hundred sites.

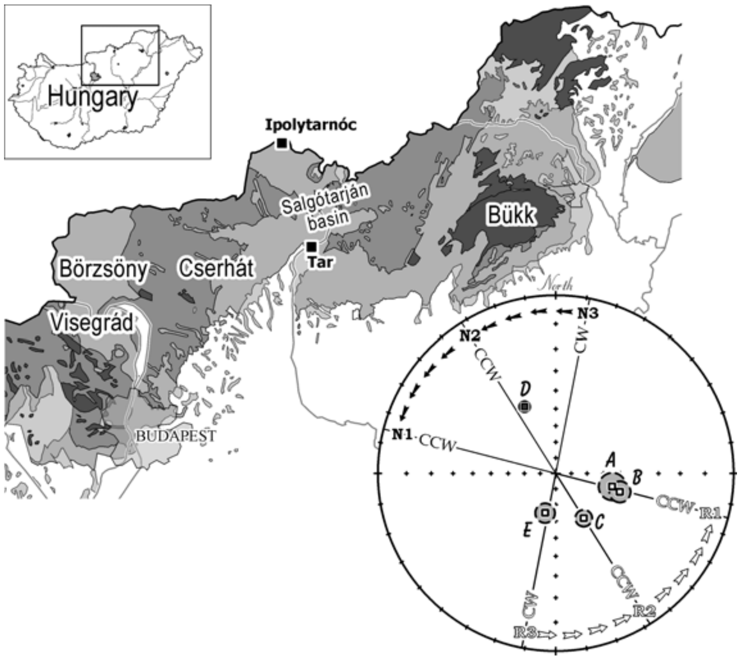

Fig. 1: The study area and some examples of the obtained palaeomagnetic directions (with the circle of confidence) compared with the expected declinations for the lower (N1–R1), the middle (N2–R2) and upper (N3–R3) tuff (ignimbrite) complexes. A) Southern Foreland of the Bükk Mts., lower ignimbrites. B) Salgótarján Basin, lower tuffs. C) Southern Foreland of the Bükk Mts., upper ignimbrites. D) Ipolytarnóc. E) Tar. All are of reversed polarity, except D.

It was found out that N1–R1 is confined to the Salgótarján Basin, and to the Bükk Mts. and their southern foreland. Sites showing N3–R3 declinations are few yet scattered all over the study area. The largest number of sites belong to the 16.0–14.5 Ma age group: they mark the onset of volcanic activity in the Visegrád Mts., in the Börzsöny Mts. and are widespread all around the Bükk Mts., cover the famous fossil footprint site, Ipolytarnóc (Fig. 1). The last occurrence was correlated with the oldest tuff horizon earlier. Apart from Ipolytarnóc, age revision is suggested on palaeomagnetic basis for several of the studied sites, among them for the quarry of Tar (Fig. 1), which was defined as the type locality for the middle tuff, by the name of Tar Dacite Tuff Formation, but turned out to belong to the upper tuff complex (Zelenka et al. 2004).

To conclude, the combined application of palaeomagnetic marker horizons and magnetic polarity information proved to be a reliable correlation tool for the Miocene volcanoclastics. The limitation of the method is, however, that it cannot be used between areas that were displaced relative to each other after the eruption of the volcanoclastics in question.

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The Same or not the Same? – A New Approach within the Taxonomy of the Ostracod Genus *Cyprideis* Jones, 1857 from Lake Pannon

Klaus Minati, Robert Buttinger, Radovan Pipik, Josef Knoblechner & Pierre Carbonel

After the Upper Sarmatian bottleneck with a loss of many species, a radiation started within the ostracod fauna inhabiting the long-lived Lake Pannon. This diversification in the Lower to Middle Pannonian (Pannonian is a local stage corresponding to the Tortonian) was the result of the ecological changes caused by the decline of the Paratethyan Sea. As a consequence a wealth of new genera and species was described. A few authors recognized the high morphological variability of ostracods induced by the changing environment.

As example to demonstrate this morphological variability we choose the genus *Cyprideis*. Valves from two Pannonian sites in the Vienna Basin (St. Margarethen and Hennersdorf, Pannon B–E, Mammal zones MN8–MN9) are compared with morphological methods based on the B-splines approach.

B-splines are piecewise polynomial curves which can be used to approximate outlines. This so-called Linhart's algorithm is adapted to ostracods and enables to illustrate even very small morphological differences in the valve outlines. Additionally, we match the fossil valves from Lake Pannon with recent and subfossil ostracods of the species *Cyprideis torosa* Jones, 1850. Our aim is to show if and how similar these latter ostracods from France, Romania and Africa are compared to the fossil ones from Lake Pannon.

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Revealing Environmental Fluctuations on Different Scales in Lake Pannon (Lower Pannonian, Styrian Basin)

Klaus Minati, Martin Gross & Werner E. Piller

An extensive regression is registered in many parts of the Pannonian Basin at the Sarmatian/Pannonian boundary, which is interpreted to coincide with the global sea level fall at the Serravallian/Tortonian boundary (Ser 4/Tor 1 of Hardenbol et al. 1998). Subsequently, the Central Paratethys turned into an isolated lake – the Lake Pannon. Beside the famous radiation of molluscs (e. g., dreissenids, lymnocardiids, melanopsids), a lot of endemic ostracod species have developed in Lake Pannon, which are also used for biostratigraphical and palaeoecological approaches.

At the western edge of the Pannonian Basin System, Lower Pannonian sediments cover most of the eastern part of the Styrian Basin. One of the best-studied outcrops is the clay pit Mataschen (approx. 40 km SE Graz), where lowermost Pannonian (*Mytilopsis ornithopsis* Zone) is exposed. The ca. 30 m thick succession starts with sandy sediments with an only poor, limnic ostracod fauna (darwinulids, candonids, ilyocyprinids), which belongs to the basal Pannonian lowstand systems tract. The ostracod faunas (cytherideids, hemicytherids, loxoconchids) as well as the overlying pelites with plant- and mollusc-remains indicate a very rapid transgression of the Pannonian Lake (transgressive systems tract). Above this about 4 m thick pelitic unit an overall coarsening upward trend with pelite - fine sand alternations, topped by large-scale cross bedded sands, reflects the transition from limnic to deltaic environment (highstand systems tract). In general, this transgressive-regressive sedimentary cycle is well understood and was part of a multidisciplinary research project (Gross 2004).

Based on these results, we now focus on environmental fluctuations on different scales around the maximum flooding surface, with special emphasis on the variations within the ostracod fauna. For this purpose, beside sedimentological studies and a gamma-ray analysis of the entire section, a sediment core of half a metre length was sampled in intervals of 0.5 cm and analysed quantitatively. The gammy-ray analysis points to a distinct cyclic sedimentation of the section as a whole, first results on the ostracod distribution in the core samples suggest cyclicity on a cm-scale.

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Oil & Gas Exploration in the Styrian Neogene: A Brief History of RAG's Activities 1951–1996

Wolfgang NACHTMANN & Richard A. NEUMAYER

RAG (Rohöl-Aufsuchungs AG) has pursued hydrocarbon exploration in Styria for about 45 years. Main target was the Styrian Basin, a western margin basin of the Pannonian Basin. To a minor degree and only for a short period the Fohnsdorf Basin, an inner-alpine basin with coal mining history, was investigated for its coal bed methane (CBM) potential.

Before RAG was awarded a Styrian concession in 1955 – covering the major parts of the Fürstenfeld and Gnas Subbasins – exploratory work had already started in 1951 under a research agreement with the Geological Survey with geological surface mapping, regional studies and the acquisition of single fold 2D-seismic. Not at least due to the rather disappointing drilling results the exploration activity in Styria was not continuous – it was characterized by phases of intensive drilling alternating with study and re-assessment ones. From a hydrocarbon exploration standpoint all wells were dry. However, many of them tested hot water and three of them, Binderberg 1, Waltersdorf 1 and Blumau 1a have not been abandoned – they are still serving as geothermal sources for spas (Fig. 1-2).

Short characterisation of the drilled wells

Übersbach 1 (TD 2692 m in Paleozoic limestones): target was a structural trap of Sarmatian, Badenian and Karpatian clastics. The well was dry, minor hydrocarbon traces, indicating existing generation within the basin, and young volcanogenic CO_2 was recorded.

Walkersdorf 1 (TD 2141 m in Paleozoic dolomites): well tested an anticlinal structure for presence of hydrocarbons within the Badenian (main target) and Karpatian. Minor oil and gas shows were observed within the Badenian and Karpatian section. The temperature of the Paleozoic aquifer is in the range of ~85 °C.

Mitterlabill 1 (TD 1781 m in "Helvetian" shales) located in the SW part of the Gnas Basin. Exploration objectives were hydrocarbons from a seismically mapped anticlinal high zone. Both objectives horizons (Badenian, Karpatian) showed only minimum gas traces.

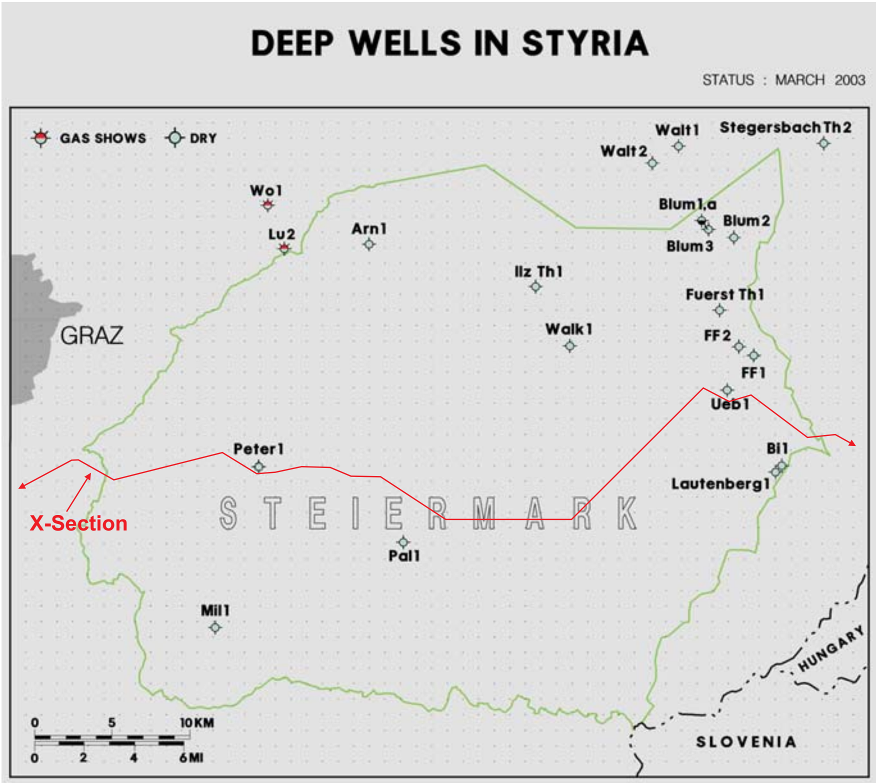

Fig. 1: Location map of wells and geological cross-section.

Paldau 1 (TD 1440 m in Karpatian vulcanites): in a more central position within the Gnas Basin. Structure type is stratigraphic, target formation are Badenian strata. No gas or oilshows were encountered.

Binderberg 1 (TD 1727 m in Paleozoic phyllites): target of this gas exploration well, located on the South Burgenland Swell, were clastics of the Badenian and Karpatian. Gas migration was assumed to come from deeper parts of the Styrian as well as from the Pannonian Basin.

The dry Binderberg 1 well was the first RAG well which was used for a geothermal project. During well assessment RAG carried out several water tests (salinity –4 % NaCl) in the deep marine coarse clastics of the Karpatian (Miocene). Some of them had remarkable CO_2 rates (70000 Nm³/d, maximum temperature >70 °C) and open water flow. The CO_2 expansion drastically reduced the temperature of the hot water on the surface. Binderberg 1 is the basis for the thermal spa Loipersdorf, which has been attracting tourists since the late 1970s.

GEOLOGICAL PROFILE

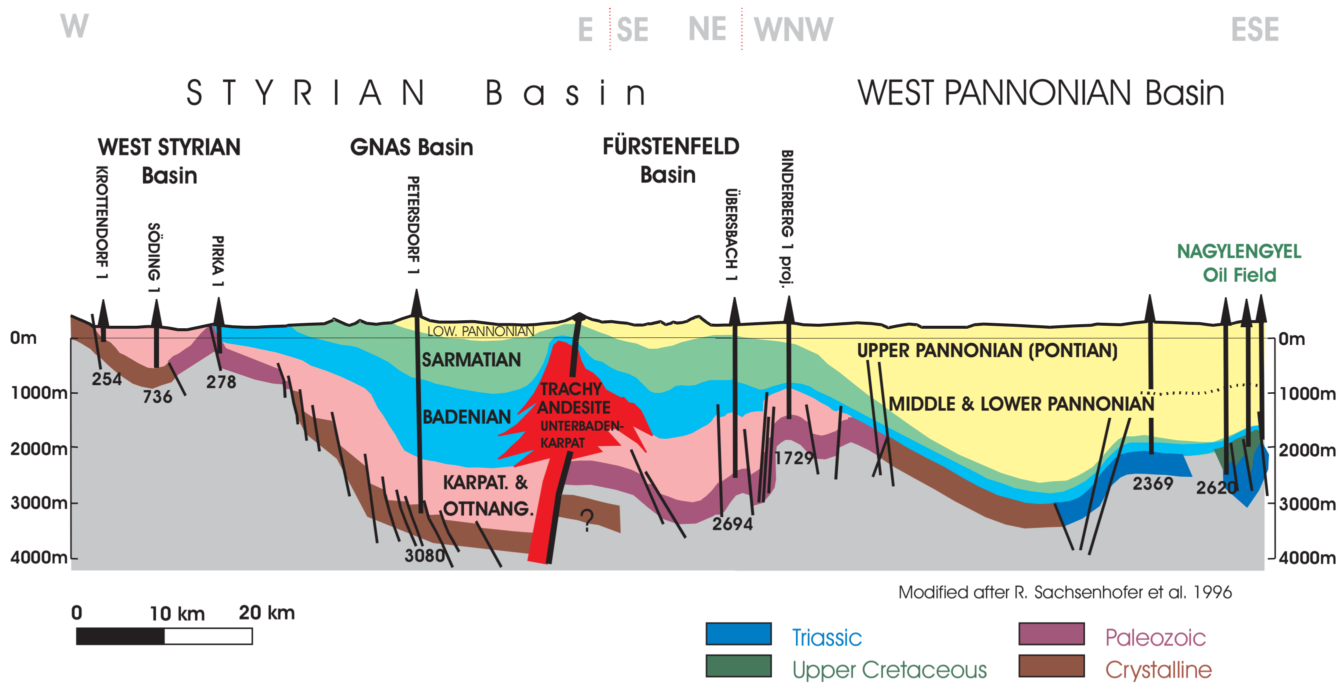

Fig. 2: Geological cross-section through the Styrian Basin.

The water is derived from the basal part of "Middle" Sarmatian (delta front sands, at approximately 1100 m). Water temperature is ~62 °C which corresponds to a geothermal gradient of about 5 °C/100 m.

Waltersdorf 1 (TD 1553 m in the crystalline basement): located in the northern shallower part of the Fürstenfeld Basin. The well concept was still based on interpretation of single fold dynamite seismic. Again the objective was gas in Sarmatian and Badenian strata, which are trapped by an antithetic fault. No hydrocarbons were encountered, all porous layers in the Sarmatian, Badenian and Paleozoic are water-bearing. Two tests in Badenian turbidites and coastal plain deposits recovered freshwater. The Paleozoic strata could not be tested because of technical problems.

The well was given to the local community. A re-entry in 1978 resulted in a water influx from Devonian dolomites (temperature 61 °C). The hot water is used for a spa (Heiltherme Waltersdorf) and for geothermal district heating.

Blumau 1/1a (TD 1907 m and 3045 m in Paleozoic phyllites) tested a domed block associated with a major NE trending synthetic fault, providing the lateral seal.

Since Blumau 1 hit the Paleozoic on the upthrown block the well was sidetracked as Blumau 1a. This well encountered a thick section of coarse clastics (alluvial fan along the growth fault) of the basal Badenian and Karpatian. In the Paleozoic rocks (Silurian–Devonian) circulation was lost several times.

A test at the top part of the Paleozoic dolomites recovered ~10 m^3 water (3600 ppm NaCl). 75 °C water temperature was measured at the surface. Traces of CO_2 and CH_4 were recorded. In later years, after re-entry oil shows were reported. 1997 the spa "Blumau" was opened. Its unconventional architecture was desiged by Friedensreich Hundertwasser, a leading member of the "Vienna School" of painters.

Arnwiesen 1 (TD 951 m within the Schöckl Nappe): this gas exploration well was drilled in the NW part of RAG's concession area, close to OMV's non commercial gas discovery Ludersdorf 1. Exploration target was gas in *Lithothamnium* limestones (Badenian) in an antithetic fault structure. No hydrocarbons were encountered.

Petersdorf 1 (TD 3080 m in the crystalline basement) chased a new play type for the Gnas Basin, mapped on base of new 2D-seismic, acquired in 1994. Main gas target was a structural trap within a prograding sequence of the Karpatian. A secondary target was identified within Lower Badenian sediments. The well reached final depth in crystalline rocks of central Alpine units. According to the log interpretation all porous sections were water bearing, therefore the well was suspended without test.

After the Petersdorf failure a careful post completion analysis of the past drilling activity and a reassessment of the hydrocarbon potential of the concession was carried out. This resulted in RAG's decision to pull out of this area and relinquish the concession (Fig. 3).

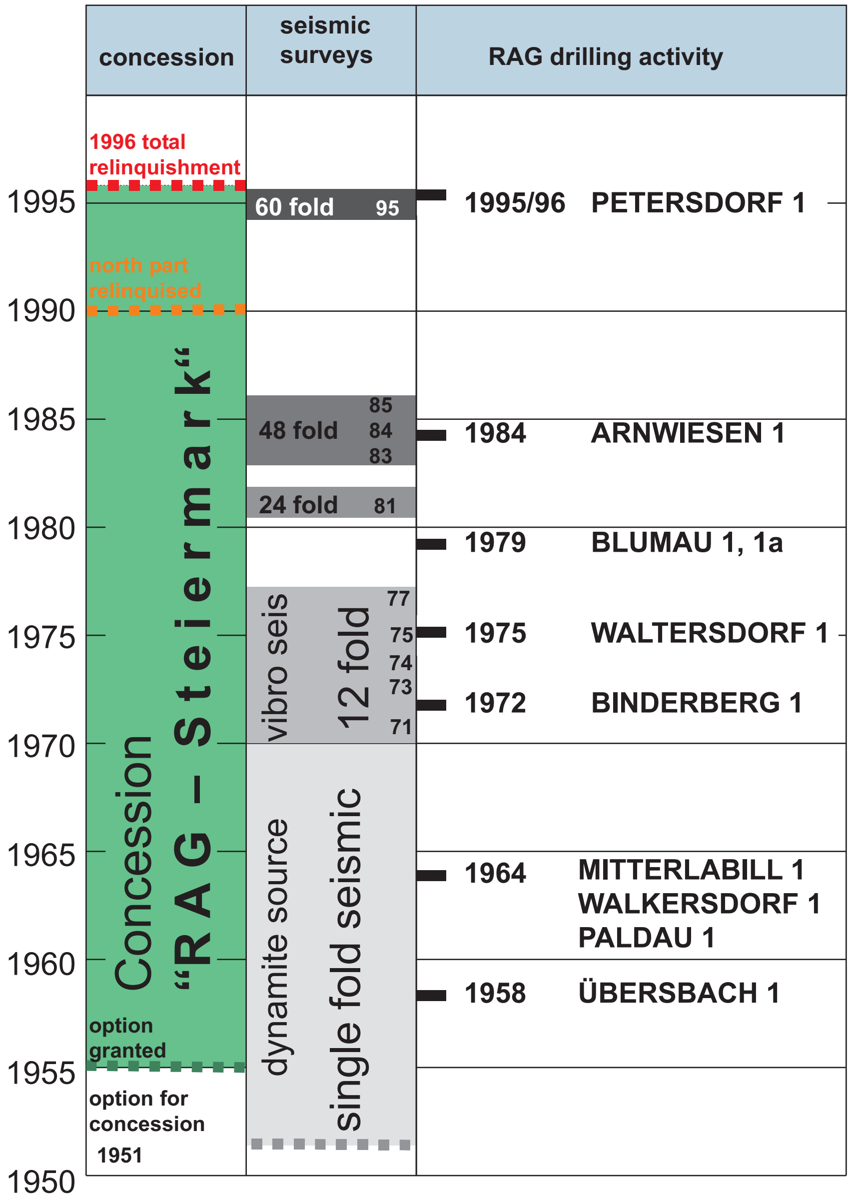

Fig. 3: Chronology of RAG-activities in the Styrian Basin.

The disappointing results of the exploration efforts in the Styrian Subbasins are caused by the relatively late and independent (different) geological history of the Styrian Basin compared to the prolific areas of the Pannonian Basin. Main sourcing within the Pannonian Basin comes from Mesozoic rocks, which are not preserved in the subcrop of the Styrian Basin. Therefore the Ottnangian and the Karpatian strata must serve as the only sources for thermal gas. TOC-rich Badenian sediments may have generated hydrocarbons through the higher heat potential near volcanic bodies. At the same time heat pulses from the Styrian volcanism may have overcooked large areas in the Styrian Basin. Contributions of bacterial gas from relatively shallow strata can be expected. Hydrocarbon-generation modelling showed start of generation shortly after deposition, due to high sedimentation/subsidence rates. Peak generation and main migration phase occurred in the Badenian. Gas quality appears to be a major concern: due to high CO_2 and N_2 contributions from the volcanism gas quality is rather poor as we know from OMV's Ludersdorf 1 tests. Adequate vertical and/or lateral seal seems to be missing for several of the drilled prospects.

CBM-Exploration in the Fohnsdorf Basin

RAG-Kohle 1 (TD 916 m in Miocene/Karpatian): in 1995 RAG conducted investigations to determine the expected gas potential (coal bed methane) of the inner-alpine Fohnsdorf Basin where lignite had been mined from the 17^{th} to the late 20^{th} century. This CBM campaign included also the exploration well RAG-Kohle 1, some 4 km SE of the abandoned coal mine. Targets of this well were to prove extension of the coal seams across the basin, to take cores from the coal bearing formation for desorption, adsorption and other analysis and to test the coal formation.

To make a long story short: the well did not encounter any coal seams; after final appraisal of conducted studies and well results the CBM-project Fohnsdorf was abandoned.

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New Findings of the Middle Miocene Biostratigraphy of the Planina Syncline (Eastern Slovenia, Central Paratethys)

Katarina OBLAK

The Badenian and partially Sarmatian biostratigraphy of the Planina Syncline (Eastern Slovenia, Central Paratethys) was investigated by using benthic and planktonic foraminiferal taxonomy. The Planina Syncline is located in Kozjansko, in the middle part of Eastern Slovenia. Palaeogeographically, it belongs to the south-western margin of the Pannonian Basin.

The Badenian beds sit discordantly on the Upper Egerian sand in the Planina Syncline. They consist of basal conglomerate, coarse-grained calcarenite or rarely of *Lithothamnium*-limestone. This is followed upwards by massive calcarenite, alternating calcarenite and marly calcarenite, and uppermost by marl. According to previous studies, the stratigraphic boundary between Badenian and Sarmatian was set at the base of Sarmatian conglomerate, which follows marl.

In my research, six sections have been sampled. All of them start with basal Badenian strata and are mostly completed with Sarmatian conglomerate. 159 samples were taken and 128 genera and 192 species or subspecies were identified. Due to their distribution six Badenian zones are defined; Lower Badenian Lower and Upper Lagenidae Zones, Middle Badenian *Pseudotriplasia robusta* and *Uvigerina* cf. *pygmea* Zones, and Upper Badenian *Bolivina dilatata* and *Virgulinella pertusa* Zones. All zones apart from the last one are rich in foraminifers, full marine environmental indicators are frequent. Contrary, late Upper Badenian Zone is recognized as having reduced total foraminiferal diversity and much reduced planktonic foraminiferal abundance. Overlying strata belonging to Sarmatian *Anomalinoides dividens* and *Elphidium hauerinum* Zones are typically brackish. The boundary between Badenian and Sarmatian was adjusted in three sections towards older strata of marl, below the Sarmatian conglomerate.

In no section all six zones are proven but it is presumable that the missing zones are present under unsampled grassy areas, which are frequent and extensive in all sections. If this is so, then there is a continuous sedimentary record from the beginning of Badenian to the Upper Badenian, and possibly into the Lower Sarmatian. The assumption of continuous sedimentation across the Badenian/Sarmatian boundary could be supported by the presence of the impoverished late Badenian *Virgulinella pertusa* Zone, which was assigned in the easternmost section as well as by the displacement of the boundary into lithological more uniform marl. In previous studies, the uppermost Badenian beds were considered to be eroded or not deposited, so the boundary between Badenian and Sarmatian is believed to be discordant in the whole area of Slovenia.

To prove my hypothesis regarding the sedimentary continuity of the studied area additional fieldwork is required. Studying microfaunal and lithological changes from the Late Badenian to the Early Sarmatian is only possible by determining the precisely position of the Badenian/Sarmatian boundary within the syncline, and vice versa. Even though the continuity is not proven, the geological transition between both stages in the Planina Syncline appears to be less dramatic than was previously thought.

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Ichnology of the Lower Badenian (Middle Miocene) Baden-Sooß core at the type locality of the Badenian (Vienna Basin, Lower Austria)

Peter PERVESLER & Alfred UCHMAN

Supported by the FWF-project P13743-BIO "Temporal and spatial changes of microfossil associations and ichnofacies in the Austrian marine Miocene" a scientific core has been drilled near the western margin of the southern Vienna Basin to a depth of 102 metres. The aim of the study was the answer to problems in biostratigraphy, palaeoecology, palaeoichnology, sedimentology, geochemistry, magnetostratigraphy and magnetic climate proxies such as magnetic susceptibility (HOHENEGGER et. al., submitted).

After splitting the core vertically and smoothing the cross section scanning and camera did digital documentation. Except several layers with primary laminations the core is completely bioturbated. Seven main ichnofabric types and several subtypes were distinguished (Fig. 1).

Trace fossils from the ichnogenera *Asterosoma*, *Chondrites*, *Nereites*, *Ophiomorpha*, *Phycosiphon*, *Scolicia*, *Siphonichnus*, *Teichichnus*, *Thalassinoides*, *Trichichnus* and *Zoophycos* can be distinguished in cross-section. *Phycosiphon* dominates the core, occurs in nearly all horizons and is accompanied in many layers by *Nereites*. Other trace fossils such as *Scolicia*, *Trichichnus* and *Zoophycos* are concentrated in the deeper portion of the core. *Thalassinoides* is completely absent in these deeper horizons, shows a maximum in the middle part and also occurs frequently in the higher portions.

Although *Phycosiphon* has no connections to the sea floor, it is common in poorly oxygenated sediments (e.g., EKDALE & MASON 1988). This trace fossil is interpreted as a structure originating from deposit feeding and indicates a high portion of particulate organic matter in the sediment. *Trichichnus* has a typically strong tendency to pyritization. It is a deep-tier trace fossil, produced by opportunistic organisms in poorly oxygenated sediments (MCBRIDE & PICARD 1991), which maybe belong to chemosymbiotic meio-infauna. *Zoophycos* and *Chondrites* are typical members of soft bottom communities settling in muddy, organic rich, dysaerobic sediments deposited under quiet conditions.

The trace fossil *Scolicia*, produced by irregular echinoids, indicates full marine conditions (e.g., BROMLEY & ASGAARD 1975; SMITH & CRIMES 1983). The salinity tolerant crustacean burrow *Thalassinoides* (FREY et al. 1984) replaces *Scolicia* in the higher portions of the core.

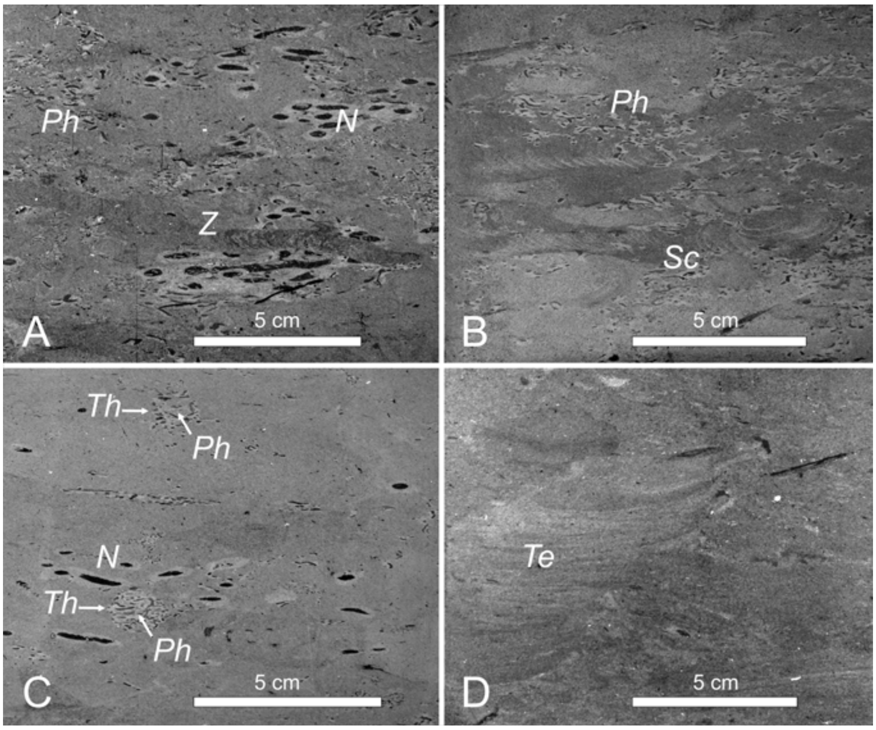

Fig. 1: A) Ichnofabric with *Phycosiphon* (*Ph*), and *Nereites* (*N*) cut by *Zoophycos* (*Z*). Metre 96.04–96.54. B) Ichnofabric with *Phycosiphon* (*Ph*) cutting and being cut by *Scolicia* (*Sc*). Metre 46.56–46.66. C) Ichnofabric with *Nereites* (*N*) and *Thalassinoides* (*Th*) filled with *Phycosiphon* (*Ph*). Metre 46.20–46.30. D) Ichnofabric with Teichichnus cut by *Phycosiphon*. Metre 26.43–26.53.

The distribution of trace fossils in this core shows a shallowing tendency indicated by the transition from the *Zoophycos* ichnofacies to a very distal *Cruziana* ichnofacies. Surprisingly, the distribution of the trace fossils shows a significant correspondence to the insolation and magnetic susceptility cycles.

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Badenian Marginal Marine Environment in the Medvednica Mt. (Croatia)

Durdica PEZELJ & Jasenka SREMAC

Miocene deposits in NW Croatia are particularly well developed at Medvednica Mt., where they outcrop in a ring-like belt surrounding the mountain.

A section with Middle Miocene clastic beds is exposed along the forest road at the locality Borovnjak (SW Medvednica). The basal part of the section is represented by conglomerates and weathered *Lithothamnium*-limestones. They are overlain with biocalcarenites and carbonate sands, containing scarce biocalclutite intercalations.

Microfossil community is, in general, preserved poorly (abraded, often with broken tests) and scarce, except in marly sediments. A total of 14 species and 8 genera of benthic foraminifera and 10 species and genera of ostracods were identified.

The biostratigraphy of the studied section is based on the standard Zonations for the Paratethys (BRESTENSKÁ & JIŘÍČEK 1978; CICHA et al. 1998). Late Badenian age (*Ammonia beccarii* Zone) was proved on the basis of dominant presence of *Ammonia viennensis*, elphidiids and miliolids, as well as ostracod species *Phlyctenophora farkasi* and genus *Neocyprideis* (*Miocyprideis*).

The interpretation of palaeoenvironment was based upon the quantitative analysis of fossil communities. Planktonic/benthic ratio, number of species of benthic foraminifera and ostracoda, Benthic Foraminiferal Number and benthic foraminifera/ostracod ratio has been determined for each standardized sample. Dominant and common species were separated, and their variations across the profile were examined. Four diversity indices: Fisher α index, Shannon-Wiener index, Equitability and Dominance have been used to define species diversity of benthic foraminifera. Benthic Foraminiferal Oxygen Index (KAIHO 1994), dissolved oxygen indicators and epifauna/infauna ratio were also estimated.

A small number of species, low faunal diversity, strong dominance of a few taxa and a small number of specimens characterize foraminiferal community. Dominant taxa *Asterigerinata planorbis*, *Elphidium macellum*, *E. crispum* and *Ammonia viennensis* are typical for shallow-marine environment, which is in accordance with the absence of planktonic foraminifera, high oxic conditions and dominance of oxic indicators and epifaunal taxa. Broken and abraded tests can indicate long-shore transport by littoral drift and tidal currents.

The most common taxa in the lower and upper part of this section are *E. macellum*, *E. crispum*, *E. fichtellianum* and *A. planorbis*, mostly typical for normal marine environments. Ostracod specimens generally participate with 8% in the communities, and the most frequent taxa are *P. farkasi* and *Loxoconcha hastata*.

Appearance of a brackish genus *Neocyprideis* (*Miocyprideis*) in fine-grained intercalations in the central part of the section, together with euryhaline ostracod taxa *Cytheridea pernota* and *Xestoleberis glabrescens*, and high percentage (>30%) of an opportunistic species *A. viennensis*, indicate the temporary input of freshwater into the basin.

Micropalaeontological features, together with sedimentological data indicate that the Upper Badenian deposits of Borovnjak were deposited in relatively turbulent near-shore marine environment with temporary oscillations of salinity.

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Miocene Central Paratethys Stratigraphy – Current Status and Future Directions

Werner E. PILLER, Mathias HARZHAUSER & Oleg MANDIC

The complex geodynamic history of the Paratethys fostered from time to time the evolution of a highly endemic biota with only limited exchange with the neighbouring Mediterranean and Indo-Pacific provinces. The resulting very peculiar fossil assemblages forced the introduction of a regional chronostratigraphic subdivision for the Western/Central and Eastern Paratethys respectively.

For the Central Paratethys we present a summarized and updated database for the individual stages, and we review the current status for correlation with the Mediterranean stratigraphic framework.

The Miocene Central Paratethys stages were defined on exclusively palaeontological criteria in type sections (holostratotypes and faciostratotypes). They are all bounded by either sedimentary hiatuses or distinct facies changes, inferred to mark lowstands in sea level, and not a single boundary stratotype has been defined. Some correlating tie-points to the Mediterranean succession are based on calcareous nannoplankton and planktonic foraminifers; magnetostratigraphic correlation is very limited. All stages can be assigned to the putatively third-order sea level cycles, with the Eggenburgian, Badenian and Pannonian Stages each spanning three cycles and the Ottnangian, Karpatian, and Sarmatian one each.

The Karpatian/Badenian boundary correlates with the Burdigalian/Langhian (Early/Middle Miocene) boundary, and the Sarmatian/Pannonian boundary correlates with the Serravallian/Tortonian (Middle/Late Miocene) boundary. The correlation to third-order cycles and the detection of astronomical signals suggest that not only a regional but also a strong global signal is present in the rock record of the Central Paratethys.

Since the current definition of a stage includes its global spread, formally defined regional stages are redundant and therefore also not necessary for the Central Paratethys. However, if stages are essentially regional, then a regional scale as for Central Paratethys would be much more appropriate.

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Morphological Disparity within Sarmatian and Pannonian Populations of *Cyprideis* from the Vienna Basin

Radovan PIPIK, Klaus MINATI, Robert BUTTINGER & Dan L. DANIELOPOL

Cyprideis pannonica is a pillar of ostracod biostratigraphic zones in the northern Lake Pannon, which characterizes the Late Sarmatian and Early Pannonian Zones "A–C" in the Central Paratethys. It differs from the second stratigraphically most important *Cyprideis tuberculata* in height and length, and in ornamentation (KOLLMANN 1960).

Morphometric outline analysis was realized on the adult female valves of two Sarmatian and two Pannonian *Cyprideis* populations from the Vienna Basin. All valves were photographed in external lateral view using a microscope and a digital camera. Optical images were processed with the Tps-dig software and for the reconstruction of valve outlines the B-splines approach adapted to ostracods was used (BRAUNEIS et al. 2006).

Only *Cyprideis* from Pellendorf were attributed to *C. pannonica* based on KOLLMANN's revision of *Cyprideis* and they were successively compared with three other ecologically different populations.

Ostracod taphocenosis of the sandy deposits of *Porosononion granosum* Biozone from Skalica is composed of brackish *Cyprideis* and marine (*Pontocythere*, *Neocyprideis*) taxa indicating sublittoral, outer estuarine conditions (FORDINÁL & ZLINSKÁ 1998).

The latest Sarmatian association of caliche-like sediments from Sankt Margarethen is composed mainly of *Cyprideis* (53 % of all individuals in wash residuum) and *Heterocypris* (37 %). Other genera – *Cyclocypris*, *Potamocypris*, *Virgatocypris*, *Loxoconcha*, *Cypridopsis*, *Candonopsis*, *Notodromas*, *Stenocypria* – reflect an input of freshwaters to saline coastal ponds or lake.

Pannonian *Cyprideis* associations from Pellendorf and Stavešice are ecologically more unified being composed of *Hungarocypris*, *Amplocypris*, *Hemicytheria* and *Loxoconcha*.

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The Styrian Tectonic Phase – A Series of Events at the Early/Middle Miocene Boundary Revised and Stratified (Styrian Basin, Central Paratethys)

Fred RÖGL, Stjepan ĆORIĆ, Johann HOHENEGGER, Peter PERVESLER, Reinhard ROETZEL, Robert SCHOLGER, Silvia SPEZZAFERRI & Karl STINGL

The "Styrian Phase" of STILLE characterizes multiple tectonic events at the Early/Middle Miocene, i. e., Karpatian/Badenian boundary. This phase is based on the observed Neogene tectonic history in the Styrian Basin, Austria. In a geologic setting, the Styrian Basin belongs to the western part of the Intra-Carpathian Pannonian Basin system. Basin formation started during the Early Miocene, probably during Ottnangian. On top of deeply eroded Austroalpine nappes, swamp and flood deposits are transgressed by the Paratethys Sea in Karpatian time.

Angular discordances and sedimentation gaps characterize the Early/Middle Miocene, the Karpatian/Badenian boundary. On top of the Karpatian, deep-water sediments of the "Steirischer Schlier" follow a series of marine ingressions of the Badenian Sea in the realm of Central Paratethys. During Badenian, tectonic activity is accompanied by extensive volcanism.

Excellent insights of these processes are represented in the outcrops Wagna brickyard and Retznei quarry (Styrian Basin, Austria). Interdisciplinary studies in sedimentology, micropalaeontology, and palaeomagnetism enabled high-resolution stratigraphy to determinate the ages of these events.

Palaeomagnetic results

In the Wagna section chron C5Cn.3n to chron C5ADn are recorded. A series of sedimentary gaps interrupt the continuous palaeomagnetic sequence. The sequence is continuous in the Retznei quarry from chron C5Bn.1n up to C5ADn, especially in the part of the nearby Rosenberg section. These measurements are supported by a recent $^{40}Ar/^{39}Ar$ datum of the crystalline tuff, ranging from 14.2 to 14.39 Ma, within chron C5ADn.

Changes in sedimentation, discordances, sedimentation gaps, as well as tectonic and volcanic activity demonstrate the Styrian Phase as a multiphase event around the Early/Middle Miocene boundary. New stratigraphic results in combination with palaeomagnetic and micropalaeontological investigations allow a timing of these events.

A major event is present between the sedimentation of the Karpatian Steirischer Schlier and the lowermost Badenian silts, with tilting of the Steirischer Schlier, and a sedimentation gap between 16.5 and 16.1–16.2 Ma. The next gap occurred around the nannoplankton zone NN4/NN5 boundary (14.74 Ma) between chron C5Br and C5Bn.1n, ranging from about 15.4 to <14.8 Ma. A third discontinuity at the base of corallinacean limestones is too short to be dated in the Wagna section. The sedimentation gap is extended in the Retznei sections from the top of Karpatian Steirischer Schlier to the base of carbonate sedimentation (larger gap between NN4 and NN5). Only in a few places sandy-silty sediments of the Early Badenian are intercalated below the carbonates. Volcanic ash layers and tuffites are deposited within the marls of zone NN5, in the overlapping range of *Praeorbulina* and *Orbulina*, which belong to chron C5ADn (14.19–14.58 Ma).

Wagna brickyard

The Wagna brickyard section comprises Late Karpatian and Early Badenian sedimentation. About 75 m of the Karpatian Steirischer Schlier are exposed, formed by a cyclic sedimentation of dark-grey, calcareous, silty shales, interbedded with dolomitic limestones. An angular unconformity separates the shales from overlying grey silts and fine sands comprising a pebble layer of reworked Steirischer Schlier. The foraminiferal fauna and shallow water bivalves mark this discordance by a strong change from deep-water assemblages of about 250 m to those of inner neritic depth (~50 m). This discordance comprehends the Early/Middle Miocene, Karpatian/Badenian boundary, thus representing a sequence boundary.

About 8 m of grey sand, silt, and few sandstone beds follow with an intercalated patch reef and fossiliferous layers. These beds are concordantly transgressed by brownish sandstone beds, where mollusc casts are abundant. The base of the sandstones is erosive. Layered corallinacean limestones of a carbonate build-up mark a distinct facies change, demonstrating a clear sedimentary discordance to the deeper sandstones.

Retznei, cement quarries

The Wagna section is continued in the cement quarries of Lafarge-Perlmooser in Retznei. A few metres of Steirischer Schlier form the base of the Badenian sedimentation, which starts locally with a small layer of silt and fine sand that is topped by a huge carbonate build-up. This build-up starts in the main quarry with a small coral reef and basal pebble layers and extends into corallinacean limestones of the Weissenegg Formation ("Leithakalk"). Marly sands drown the top of the build-up and carbonate sedimentation ends after starting intense volcanic activity. Basinwards the limestones consist of transported material in a deeper water slope facies. Silty and sandy marls with some sandstone layers onlap the build-up and transgress over the limestones. Rich foraminiferal faunas point to a deepwater environment of 150 to 300 m.

Biostratigraphy

With *Globigerinoides bisphericus* and markers of the calcareous nannoplankton zone NN4 the Steirischer Schlier biostratigraphically belongs to the Karpatian. The benthic foraminiferal marker *Uvigerina graciliformis* is common. Just above the first angular discordance, *Praeorbulina* marks the Middle Miocene, Badenian, which is correlative to the basal Langhian. Within the Badenian part of the Wagna section the NN4/NN5 boundary is observed at the discordance below the fossiliferous brown sandstone beds. A next marker presents the FOD of *Orbulina suturalis* beginning with the corallinacean limestones near the top of the Wagna section. *Praeorbulina circularis* and *Orbulina suturalis* occur together also in the basal marls of the Retznei section topping the corallinacean limestones. In the upper part of this section, *Praeorbulina* is reduced in number and size. Benthic assemblages correspond to the typical fauna of the Early Badenian Lagenidae Zone with *Uvigerina macrocarinata* and *Vaginulina legumen*. The nannoplankton zone NN5 is recorded throughout the section and is stratigraphically limited by the *Helicosphaera waltrans* horizon.

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Predatory Drilling Frequencies in Lower Miocene (Karpatian) Near-shore Molluscan Assemblages from the Locality Laa (Lower Austria)

Jennifer A. SAWYER & Martin ZUSCHIN

Karpatian molluscan assemblages of the Central Paratethys occur in restricted environments and have well-known species-abundance patterns. They are only preserved from near-shore settings and, compared to the shelf assemblages of the Badenian, are characterized by rather low diversity (species richness and evenness). To date, however, virtually nothing is known about ecological interactions between molluscs and their shell-drilling predators from these assemblages. Here we show that drilling intensities at the locality Laa are generally low, but differences between higher taxa and among abundant species are evident.

The overall drilling frequency (DF), calculated from 2451 molluscan shells was only 5.2 %, but differed between bivalves (n = 474, 4.4 %) and gastropods (n = 1977, 5.4 %). Correcting predation frequency estimates for disarticulated valves increased the overall molluscan drilling frequency to 5.8 % and that of bivalves to 8.9 %. The bivalve *Corbula gibba* was the single abundant species with relatively high drilling intensities (n = 137, corrected DF = 13.1 %), but the most abundant bivalve species, *Pitaria roulini*, had a corrected DF of only 5.1 % (n = 155). The most abundant gastropod species, *Agapilia pachii* (n = 845), had an exceptionally low drilling frequency of only 2.1 % but all other abundant gastropod species – *Granulolabium bicinctum* (n = 660, DF = 7.9 %), *Potamides theodiscus* (n = 156, DF = 8.3 %) and *Cyllenina ternodosa* (n = 98, DF = 6.1 %) – remained also well below drilling frequencies of 10 %.

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Sequence Stratigraphy in the North-eastern Part of the Styrian Basin

Marcellus G. Schreilechner & Reinhard F. Sachsenhofer

Three high resolution seismic lines were acquired in the NE part of the Styrian Basin to describe the hydrogeological situation and to locate new wells for the regional water supply. Two lines are situated in the N–S trending upper Lafnitz (Fig. 1) and Stögersbach valleys (Fig. 2a, b). The third line is a W–E trending connecting line (Fig. 2c, d). The seismic lines were used together with logs from three wells to establish a sequence stratigraphic framework for the Neogene deposits. Sequences with an order higher than three will be named in the following with rising indices. The Neogene basement can be identified as a discontinuous reflector with partly high amplitudes. An internal reflector within the Lower Miocene section is tentatively taken as the Ottnangian/Karpatian boundary, although the presence of Ottnangian rocks remains unclear. The top of the Lower Miocene – Styrian Unconformity – forms a reflector with high amplitudes and partially with top laps representing the upper part of a Karpatian Highstand Systems Tract (HST; Fig. 2a, b).

The Styrian Unconformity is overlain by three prograding units (HSTs), which partly are separated by erosive surfaces. The HSTs can be related to three 3rd order sequences of Badenian age (BAD-1 to BAD-3), which are local representatives of the global cycles TB 2.3, TB 2.4 and TB 2.5 (Haq et al. 1988; Hardenbol et al. 1998).

The Sarmatian succession is subdivided into three 5th order sequences (SAR-1.1.1 to SAR-1.1.3) and one 4th order sequence (SAR-1.2) composed mainly of Transgressive Systems Tracts (TST) and HSTs. Only the lowermost Sarmatian rocks were deposited during a time with falling sea level (forced regression package, Falling Stage Systems Tract (FFST)) forming the Lowstand Systems Tract (LST) of SAR-1.1.1. LSTs of the overlying sequences are not observed. This is either because they are located in a distal position not covered by the seismic lines, or because they are beyond their resolution. Reflection geometries suggest the presence of carbonate build-ups within sequences SAR-1.1.1 and SAR-1.1.2 (Fig. 1). These build-ups may form equivalents of carbonate rocks exposed in the Hartberg area. The following sequence (SAR-1.1.3) completes the deposition of the Lower Sarmatian which is a 4th order sequence named SAR-1.1 (= LS-1 of Harzhauser & Piller 2004) and part of the 3rd order sequence SAR-1 (= TB 2.6 of Haq et al. 1988 and Hardenbol et al. 1998). Note that progradational patterns in SAR-1.1.3 are not well visible (Fig. 1-2), because most of the sediments were deposited perpendicular to the direction of the seismic lines.

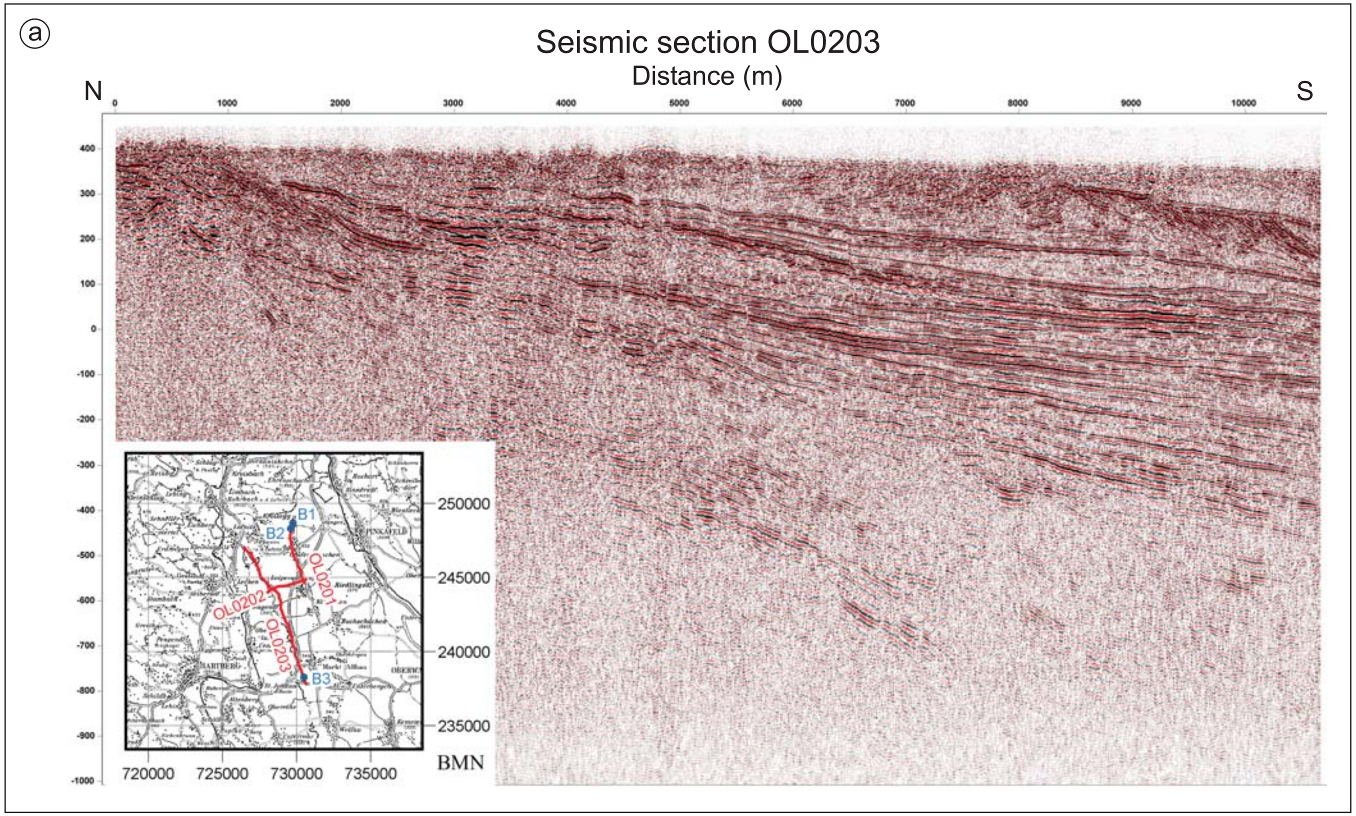

Fig. 1: a) N–S trending seismic section in the upper Lafnitz valley (Joanneum Research).

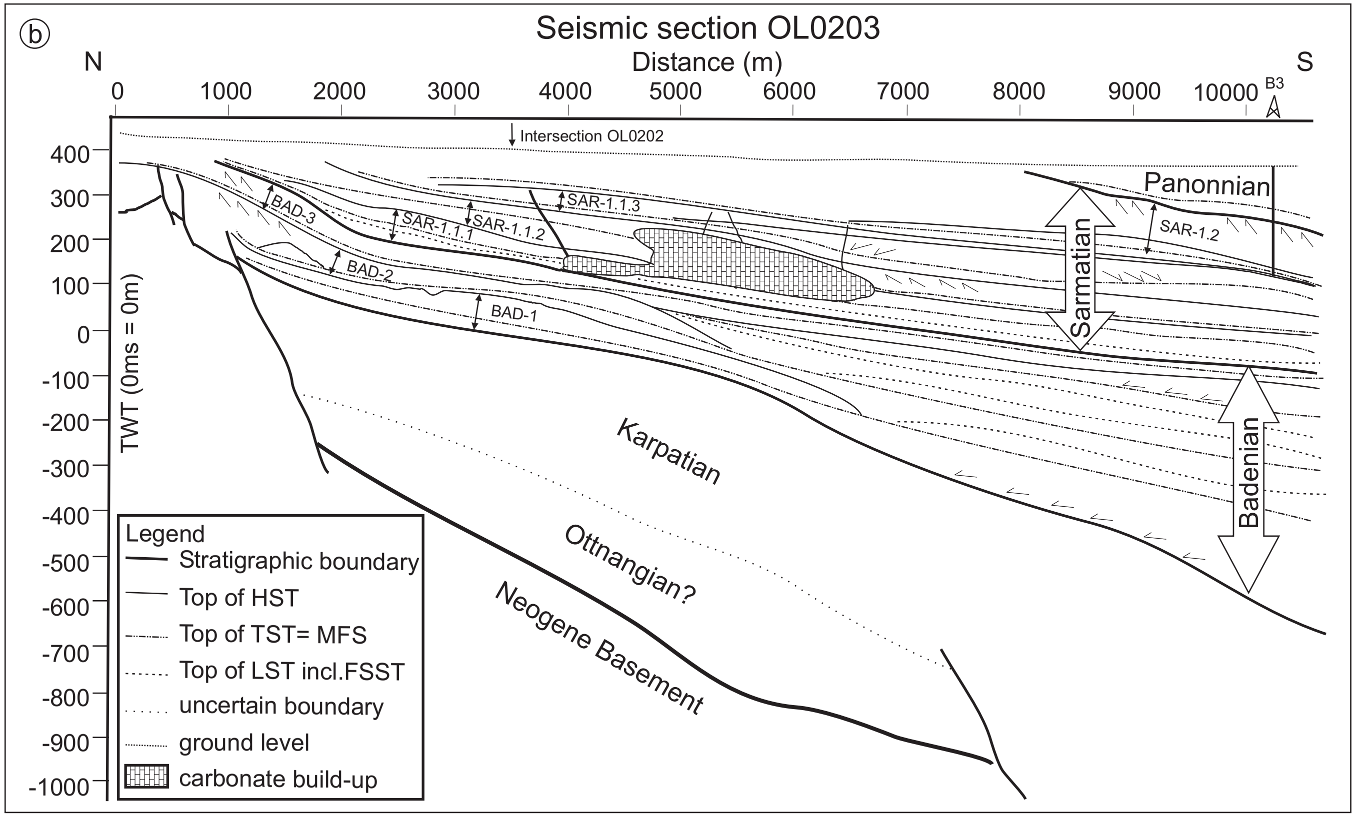

Fig. 1: b) Corresponding interpretation (cf. Fig. 1a).

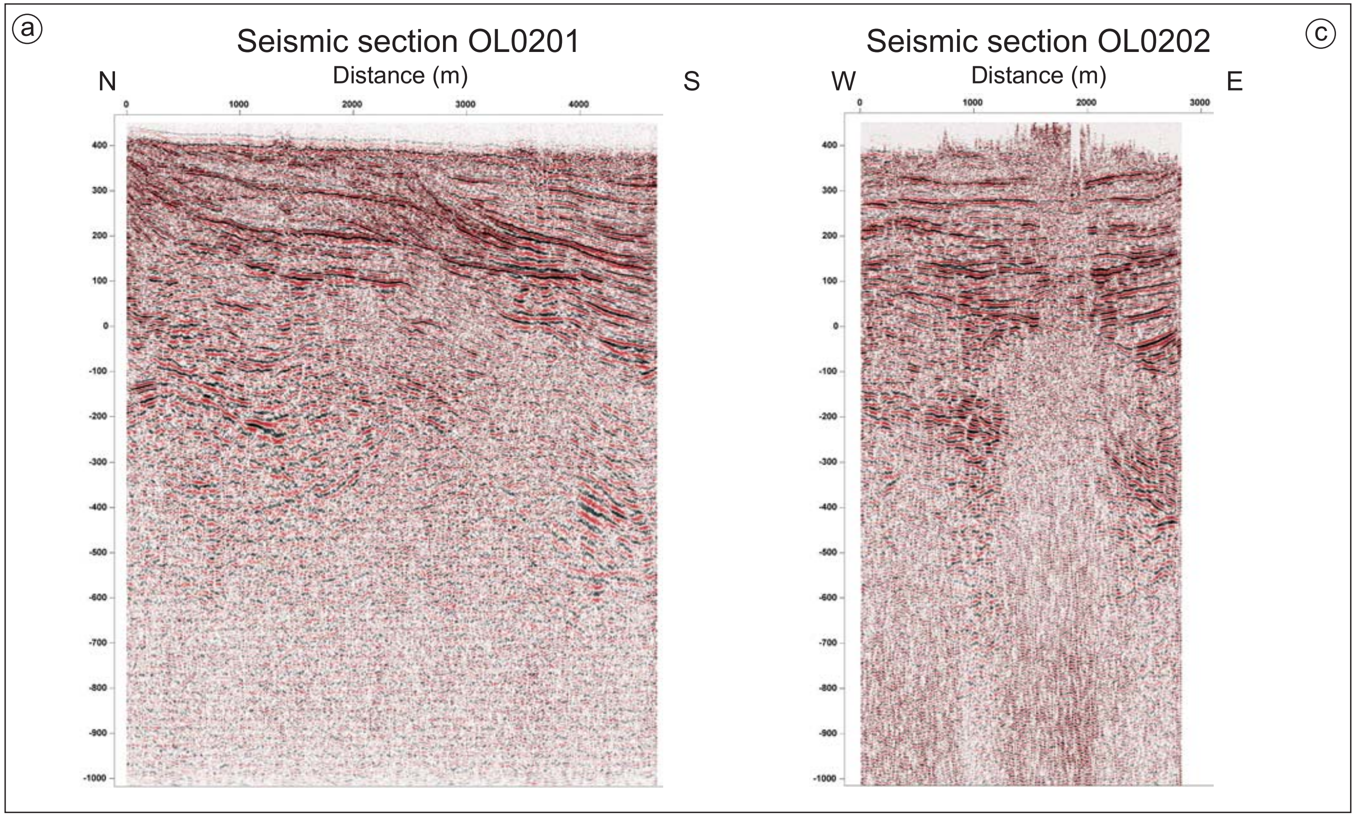

Fig. 2: a) N–S trending seismic section in the Stögersbach valley. c) E–W trending connection seismic line (both Joanneum Research).

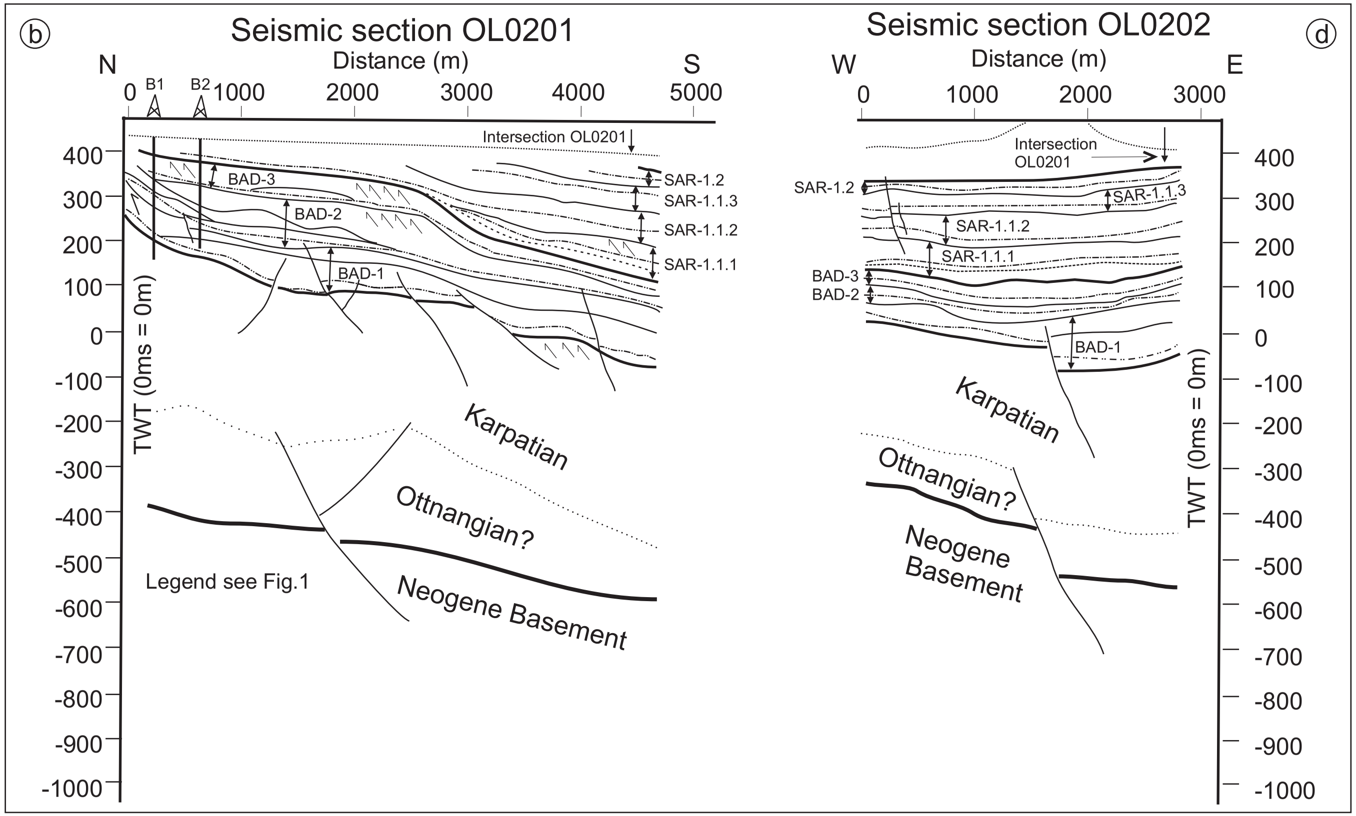

Fig. 2: b) Corresponding interpretation (cf. Fig. 2a). d) Corresponding interpretation (cf. Fig. 2c).

Thick southward prograding delta sediments occur in the southernmost part of line OL0203 near Markt Allhau (Fig. 1). They represent Upper Sarmatian sediments and can be related to the 4th order sequence with the denotation SAR-1.2 (US-2 after HARZHAUSER & PILLER 2004). An erosive surface on top of the delta sediments marks the Sarmatian/Pannonian boundary (KOSI et al. 2003).

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Dinoflagellate Cysts at the Karpatian/Badenian Boundary of Wagna (Styrian Basin, Austria)

Ali Soliman & Werner E. Piller

Dinoflagellate cysts are described from the locality Wagna (Karpatian/Badenian, Early/Middle Miocene) for the first time. The detected assemblages include 38 taxa and provide new biostratigraphical as well as palaeoenvironmental information. The Karpatian/Badenian boundary is clearly marked in all three studied sections by the first occurrences of *Operculodinium*? *borgerholtense* and *Batiacasphaera sphaerica* with the onset of the Badenian. Generally, dinocyst diversity is relatively low in all studied samples but a distinctive decline just below the Karpatian/Badenian boundary is recorded. This is in accordance with foraminiferal data and coincides with the 3rd order sea level fall at the Karpatian/Badenian (Early/Middle Miocene) boundary. In contrast to calcareous planktonic foraminifers, organic-walled dinocysts seem not to be affected by higher nutrient levels, which may have been induced by increased volcanic activities during the Karpatian.

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Upper Badenian Dinoflagellate Cysts of Bad Deutsch Altenburg, Vienna Basin, Austria

Ali SOLIMAN & Werner E. PILLER

A dense array of fully cored boreholes was drilled in the area of Bad Deutsch Altenburg (Lower Austria). The recovered cores revealed Middle Miocene sediments of a mixed carbonate-siliciclastic regime, which transgressively overlie a basement of Mesozoic dolomites. The Miocene successions contain a variety of facies of a generally transgressive development. Palynological analysis of 87 samples out of 10 boreholes (down to 100 m below surface) has revealed a diversity of dinoflagellate cysts, acritarchs, prasinophytes, foraminiferal test linings, embryophyte spores and pollen, and fungal spores.

Dinoflagellate cysts, in particular, have been studied in detail, including identification to the species level and relative quantification. The results represent the first systematic treatment of Upper Badenian (Middle Miocene) dinoflagellates from the Vienna Basin. Some stratigraphic marker taxa of dinoflagellate cysts, as *Unipontidinium aquaeductum*, *Labyrinthodinium truncatum* and *Operculodinium*? *borgerholtense*, are consistent with a Middle Miocene age based on foraminifers, which indicate planktonic foraminiferal zone M7. The dinoflagellate assemblages reflect a shallow water environment with an open marine influence for some intervals. Some horizons show increased influence of freshwater which leads to a high abundance of protoperidiniacean taxa as *Selenopemphix* and a dominance of reworked Cretaceous and Eocene species in some boreholes, especially in the NW part. Subtropical to tropical climate conditions can be deduced from the presence of some thermophilic species as *Tectatodinium pellitum*, *Melitasphaeridium choanophorum* and *Tuberculodinium vancampoae*.

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Sequence Stratigraphy of the Late Badenian & Sarmatian (Serravallian) of the Eastern Part of the Vienna Basin – Deltaic to tidal flats environment

Bohuslava Sopková, Adriana Škulová, Jana Hlavatá & Michal Kováč

In Miocene sedimentary record of the Vienna Basin, similarly as in other basins of the Pannonian Basin System, frequent relative sea level changes of global as well as of local character are registered. These well recognizable sea level fluctuations can be detected in palaeo-depth of sedimentary environment as well as in the shift of shoreline.

Our study was focused on the Late Badenian and Sarmatian strata on the eastern margin of the Vienna Basin, in Slovakia. In terms of the Mediterranean time scale, Late Badenian and Sarmatian coincide with Middle Miocene Serravallian stage established for the whole Central Paratethys region. Serravallian designates the time interval of 13.65–11.61 Ma (Gradstein et al. 2004).

Both, Late Badenian as well as Sarmatian, represent two single 3rd order cycles, which could be more or less related to the Mid-Miocene shoreline shifts within the whole Mediterranean (Kováč et al. 2004).

Late Badenian cycle in the Vienna Basin represents a single 3rd order cycle of relative sea level change, that is comparable with TB 2.5 cycle sensu Haq et al. (1988) and the time span between the boundaries Ser-2 (13.65 Ma) and Ser-3 (12.7 Ma) determined by Hardenbol et al. (1998), as well. The Sarmatian refers to the time interval between 12.7 and 11.61 Ma. In Vienna Basin the Sarmatian cycle comprises a single 3rd order cycle, which is equivalent of the TB 2.6 cycle of relative sea level change according to Haq et al. (1988) and the Ser-3 (base) and Ser-4/Tor-1 (top) boundaries of Hardenbol et al. (1998).

The existence of the previously mentioned 3rd order cycles was proved in case study area. In addition, based on the electrosequence analysis of the well logs (SP, RAG), seismic profiles, biostratigraphy and sedimentology of obtained drill cores we attempted to identify cycles of the 4th or even lower order within the Mid-Miocene sedimentary record. Generally, we have traced four 4th order cycles. Two cycles comprise Late Badenian strata (lower Late Badenian 4th order cycle - LB1, upper Late Badenian 4th order cycle - LB2) and the other two cycles (Lower Sarmatian - Sa1, Upper Sarmatian - Sa2) are assigned to the Sarmatian stage. Above-mentioned 4th order Late Badenian cycles refer rather to local impulses, than to the global sea level fluctuation.

LB1 and LB2 were forced more likely by local delta lobes switching. Beside this, Sa1 and Sa2 can be well correlated with the development of the Sarmatian sedimentary record in the Austrian part of the Vienna Basin (Harzhauser & Piller 2004) and might be related to regional shifts of the Vienna Basin shoreline.

Another goal was to establish the development of depositional environment in area of interest. The lower Upper Badenian sedimentary architecture and lithofacies show a gradual transition from the basinal environment with low oxygen content to the environment of prograding proximal delta setting (prodelta). Toward the overlying strata the Upper Badenian depositional environment became more and more shallower. This shoaling was forced by eastward progradation of deltaic clinoform body influenced by increasing sediment supply (causing the onset of forced regression). This progradation is detectable on the well log profiles as well. Following development of the depositional environment in space and time within the Upper Badenian strata could be established: basin plain – prodelta – delta front with prograding mouth bars – lower delta plain with distributary and interdistributary areas displaying common distributary channel avulsion, development of crevasse splays.

Sarmatian sedimentary record reveals deposition in a shallow brackish environment. During Lower Sarmatian, the sedimentation in the studied area passes continually from the Upper Badenian, on the lower delta plain. Further upwards, the well log study and core analysis unambiguously point to the environment of tidal flats, indicated by clays and incised channels. Present silts and sands often comprise flaser and lenticular beddings, thus we suppose deposition mainly in the intertidal to subtidal zone with the tidal flats. At the end of the Lower Sarmatian increased input of material was detected, what triggered the facies shifting from the subtidal through intertidal towards the supratidal zone. This is documented by complex network of channels with sand bars yielding clastic material derived from NW–N, together with interdistributary areas represented by swamp and marsh systems. Character of tidally influenced marshes continued to the end of the Lower Sarmatian.

The onset of the Upper Sarmatian is detected by the network of flat incised channels on the tidal flat with synchronous sand ridges and reworked sandy bodies by coastal currents. Upwards, gradual flooding within regressive phase of the Late Sarmatian has been observed. We suggest sediment load carried by channels to be reworked by coastal currents mainly of tidal and long-shore character, forming some kind of barriers triggering the sedimentation in protected bays or lagoons with possible ebb-tidal deltas. At the end of the Upper Sarmatian, we suggest subaerial deposition, evidenced by occurrence of lignite layer.

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Deltaic Parasequences on Gamma Logs, Ultra-high Resolution Seismic Images and Outcrops of Lake Pannon Deposits

Orsolya Sztanó & Imre Magyar

The Late Miocene Lake Pannon got finally filled up by large deltaic systems (Bérczi & Phillips 1985), shaping wide morphological "shelves" in the lake. These developed mainly by accumulations of inner-shelf deltas passing repeatedly due to recurring floodings of former delta plains. In boreholes where only wireline logs and small cores are available delta front to delta plain deposits are assigned to Újfalu Formation (Juhász 1994). They also crop out in cliffs as Tihany Fm. along Lake Balaton (Müller & Szónoky 1990). In addition, their sedimentary architecture can be revealed by ultra-high resolution seismic images acquired on the recent lake.

The delta plain deposits are built up of 2–8 m thick coarsening upwards units, made up of cyclic repetition of marls, silts, sands and organic-rich clays, palaeosoils or thin lignite seams. The marls contain shell lag or shell-rich beds above the cycle boundary consisting of typical "caspi-brackish" fauna indicating a connection towards the open lake, but also showing the influence of freshwater input (i. e., *Congeria balatonica*, *C. triangularis*, *Dreissena auricularis*, *Lymnocardium decorum*, *L. apertum*, *L.* cf. *penslii*, *L.* cf. *secans*, *Prosodacnomya* sp., *Prososthenia* sp., *Melanopsis fuchsi*, *M. cylindrica*, and *Unio mihanovici*). The overlying cross-laminated, silty, fine-grained sand beds reveal combined effect of currents and waves, but wave-formed foreshore deposits are very rare. The organic-rich clays at the top of the cycles contain exclusively freshwater forms (i. e., *Anodonta*, *Planorbarius*, *Gyraulus*, helicids, sphaerids, and other planorbids). In outcrops where the cycles are smaller (2–3 m only), intercalations of medium to fine-grained cross-stratified sands with erosional base up to a thickness of 0.5–2 m are common.

As pilot studies, gamma-ray measurements were carried out along the walls of two large outcrops. The obtained gamma-ray logs reflect the cyclic lithological character of the successions and despite the differences in scale they can be used to compare our data to "traditional" well log data.

High resolution and ultra-high resolution single-channel seismic sections acquisited on Lake Balaton show 0–3 m Holocene mud and the sequence architecture of Lake Pannon deposits. The 100–150 m thick progradational character of the Tihany Fm. over prodelta clays/marls to sands was recognized, as well as minor units, which were interpereted as „local occurrence of small coarse-grained prograding deltas" (Sacchi et al. 1998).

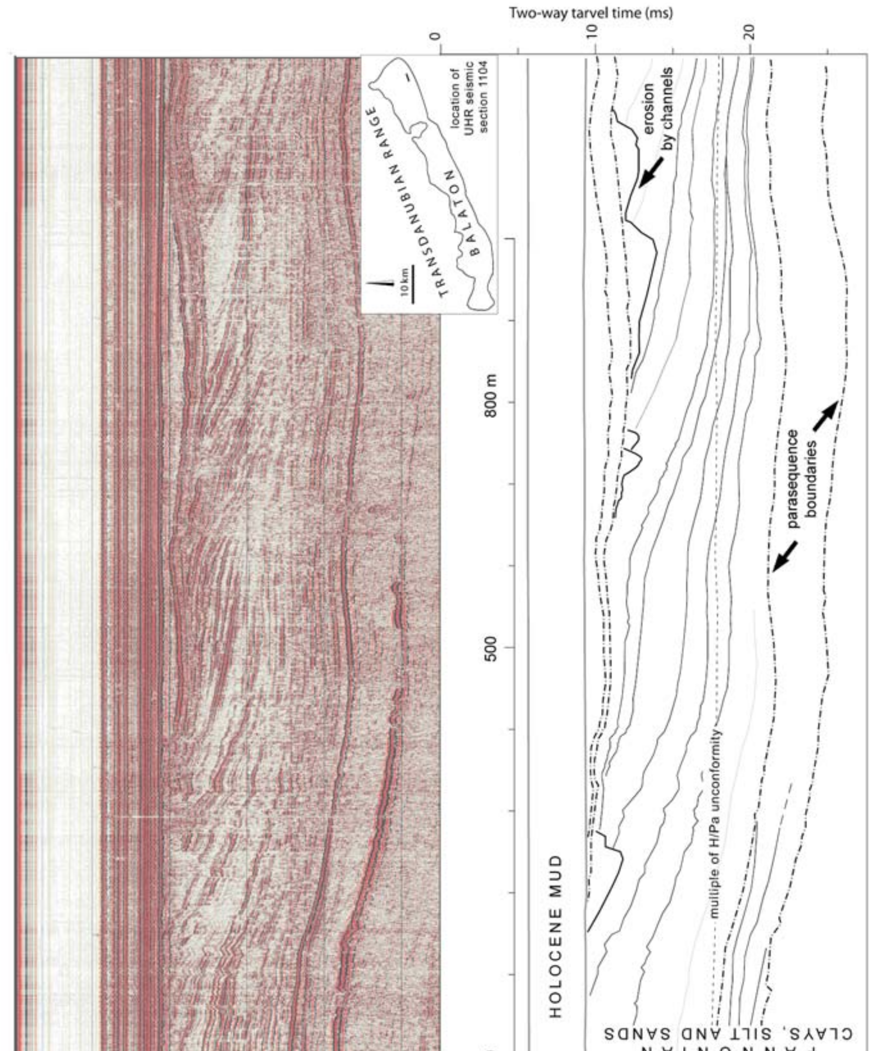

Fig. 1: Gently folded Lake Pannon deposits comprise deltaic parasequences on ultra-high resolution seismic section. Parasequence boundaries are high-amplitude reflections characterized by downlaps and/or offlaps of weaker sigmoidal reflections. Below parasequence boundaries seismically chaotic units with erosional base are common.

During the last few years more than 230 km seismic sections were measured in a semi-three dimensional net of 100–200 m. Small unconformity-bounded progradational units of about 2–10 m thickness can be mapped. The unconformities are mostly shown as high amplitude, good continuity reflection with offlaping or downlapping terminations. The slope of progradational beds has very low angle (0.2–0.8°). Below the top of the units weak, poorly? bedded reflections above 1–3 m deep, 50–200 m wide erosional truncations appear (Fig. 1). The size and geometry of the progradational units and the erosional features are in good agreement with close field observations and can be interpreted consistently.

The few metre thick sedimentary cycles seen in outcrops, on gamma logs and on seismic images are interpreted as parasequences developed on the plains of 50–100 m thick "shelf-delta" bodies. The starting member of each cycle was deposited in shallow non-agitated waters close or below wave base, in partly restricted areas, like interdistributary bays. These are overlain by deposits of progressively shallower, slightly agitated water. The filling up occurred in a progradational pattern directed by crevassing on the higher delta plain. As the bays were filled up, vegetated marshes were formed with several minor channels networking on the plain. Parasequence formation was mainly controlled by autocyclic switching of distributaries and relative lake-level variations of a few metres amplitude.

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Middle Miocene Ostracods from the Działoszyce Trough, Northern Part of the Carpathian Foredeep

Janina SZCZECHURA

Middle Miocene (Badenian–Sarmatian) ostracods were sampled from two sites (Posadza 10S and Szczytniki 11S) situated in the Działoszyce Trough, i.e., the northernmost part of the Carpathian Foredeep, about 40 km SE from Cracow. In the Posadza 10S borehole, evaporites spanning the entire Badenian were found, while the single sample from Szczytniki 11S borehole suggests its Sarmatian date. In these geological sections three (I-III) main assemblages of ostracodes may be distinguished, of which I-II referred to the Badenian, while III to the Sarmatian:

I: Evidently deep-sea and (palaeo-)geographically broadly distributed association is represented by *Argilloecia*, *Buntonia*, *Bythocypris*, *Cnestocythere*, *Costa*, *Cytherella*, *Cytheropteron*, *Eucythere*, *Eucytherura*, *Henryhowella*, *Krithe*, *Nipponocythere*, *Paijenborchella*, *Parakrithe*, *Pterygocythereis*, *Saida* and *Xestoleberis*. It is moderately abundant and markedly diversified in the lowest part of the section, corresponding to the *Globigerinoides* ecozone, distinguished as assemblage Ia, whereas less diversified and less frequent, represented by *Argilloecia*, *Henryhowella*, *Krithe* and *Parakrithe* in sediments underlying evaporites, corresponding to the *Globigerina* ecozone, designated as asemblage Ib.

II: A new ostracode assemblage (following samples without ostracods), consists of rather numerous specimens, both adults and juveniles, assigned to *Xylocythere* and ?*Microxestoleberis* (or ?*Microceratina*). Pyrit infillings in the foraminiferal tests as well as pyritised wood remains suggest their peculiar environment. Interestingly, both these taxa occur among the much more diversified and rather exotic (when consider Middle Miocene Central Paratethyan microfauna) ostracods described from the Upper Badenian deposits of the Upper Silesia, SW Poland (AIELLO & SZCZECHURA 2004).

III: Shallow marine forms contain *Aurila* (juveniles), *Callistocythere*, *Cytherois*, *Leptocythere* and *Polycope* representatives. Members of this ostracode assemblage, including almost identical *Polycope* species, which were described from the Sarmatian of the other part of the Polish part of the Carpathian Foredeep (SZCZECHURA 2000), as well as from the Upper Badenian of the Upper Silesia (AIELLO & SZCZECHURA 2004).

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An Elevation Correlated Map of the Neogene in the Styrian Basin

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This article contributes to a progress report on a digital map of the Styrian Basin (as part of the Alpine Orogen–Pannonian Basin transition zone), in which we correlate marker horizons across the transition zone in elevation and time. The Styrian Basin was inverted about 7–10 Ma ago and is currently characterized by a hilly landscape between 200 and 600 m in elevation. In the bounding orogen, mountains rapidly rise to 2200 m asl. A series of conspicuous features in the basin indicate that the region experienced a complicated uplift history during the inversion of the basin margin. These include asymmetric valley profiles, parallel orientation of drainages in discretely defined zones of the basin and others.

The aim of the map is to understand the relative importance of erosion driven incision and tectonic uplift in the shaping of the surface morphology in the transition zone. For this we extract the tectonic component by mapping the elevation of marker horizons of constant age and equivalent deposition environment across the basin. As marker horizons we use various Neogene sediments like coeval fluvial terraces and shallow marine deposits in the basin. Currently we use existing maps, and preliminary dating of cosmogenic nuclei from cave deposits as well as unpublished information. Further work will use low temperature geochronology, morphological mapping and numerical landform modelling to constrain the uplift history in space and absolute time.

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Cyclostratigraphic Dating in the Middle Miocene (Lower Badenian) of the Southern Vienna Basin

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In the southern part of the Vienna Basin, a 102 m long scientific drill hole was cored in Middle Miocene sediments, from the subsurface at the type locality of the Badenian, the old brickyard Baden-Sooß (Lower Austria).

The succession consists of more than 95 % marls and marly shales of the "Badener Tegel" (Baden Group). Biostratigraphic investigations on foraminifera (mainly lower part of Upper Lagenidae Zone) and calcareous nannoplankton (standard zone NN5) indicate an Early Badenian (Langhian) age. The main lithologies are bioturbated, medium to dark grey marls and shales with carbonate contents between 11 % and 25 % and organic carbon percentages between 0.35 and 0.65. Rare intercalations include up to 20 cm thick sand layers with some shell debris and a light-grey 5 cm thick tuff. A distinct m-thick interval around 84.5 m displays a fine mm-scale light-dark lamination with minor bioturbation. Grain size analysis of the marls indicates mainly silty clays. Mean grain size ranges from 2–4 μm. The sorting is rather poor. No distinct grain size trend has been recognized from top to bottom of the core. The marls are interpreted as hemipelagics, being mainly a mixture of pelagic biogenic carbonate and terrigenous clay and silt. The organic carbon-carbonate data follow a dilution controlled siliciclastic flux with a fluctuation in sediment supply.

Cycles in carbonate content, organic carbon content and magnetic susceptibility have been identified by power spectra analysis.

Over the complete core, spectral analyses on magnetic susceptibility demonstrated four significant ($p = 0.01$) peaks with the periods of 40.3, 23.2, 11.1 and 8.3 m and an additional peak at 1.6 m. The lower, tectonically undisturbed part of the core shows cyclicity based on power spectrum analysis of carbonate content (peaks at 44.9, 22.4, and 15.4 m), almost identical to the magnetic susceptibility.

The percentage content of organic carbon demonstrates in spectral analyses largely similar peaks (35.3, 22.4, and 11.2 m), where the second peak is identical to the carbonate content and the third to magnetic susceptibility.

Using cross-correlation, periods around 40 m correlate significantly with the 100 kyr^{-1} eccentricity cycle, the ~20 m periods with the obliquity cycle, and the 15 to 11 m periods with both precession cycles.

This equalization enables the calculation of an average sedimentation rate of 1.14 mm y^{-1}. Wavelet transformation was used to obtain the position of the cycle peaks in the profile. Cross-correlation with orbital cycles (La 2004) and the time frame given by biostratigraphic data results in the most probable dating of the Baden-Sooß core between 14.358 Ma ± 1 ka and 14.163 Ma ± 9 ka.

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Karpatian and Badenian Molluscan Assemblages of Austria – A Quantitative Approach to a Major Faunal Turnover in the Central Paratethys

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The boundary from the Lower to the Middle Miocene of the Paratethys is characterized by a well-known major change of molluscan assemblages. Here we present quantitative data from 3 Lower Miocene (Burdigalian, Karpatian) and 4 Middle Miocene (Langhian, Badenian) localities to capture the major features of this faunal transition. 87 bulk samples, comprising more than 21,000 shells, were taken from shell beds and all molluscs >1 mm were studied quantitatively and sorted into more than 400 species. Ordination methods indicate strong similarities of Karpatian assemblages (16 samples from Laa, Neudorf, Kleinebersdorf), but strong differences between Badenian assemblages (69 samples from Grund, Immendorf, Niederleis and Gainfarn). Most importantly, the differences between Karpatian and Badenian assemblages are smaller than the differences observed among Badenian assemblages. The similarities between Karpatian assemblages are mostly due to the near shore palaeogeographic position of the respective localities. The striking differences in quantitative composition among Badenian localities are probably due to heterogeneous environments present on the Badenian shelf of the Central Paratethys. Ordination methods indicate the presence of a gradient from near shore Karpatian assemblages, with Neudorf showing a somewhat more open marine molluscan composition, to inner shelf Badenian assemblages. Our quantitative study favours a strong facies change at the Lower/Middle Miocene boundary as main reason for the observed faunal turnover; there is no indication of an ecological turnover in molluscan composition.

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