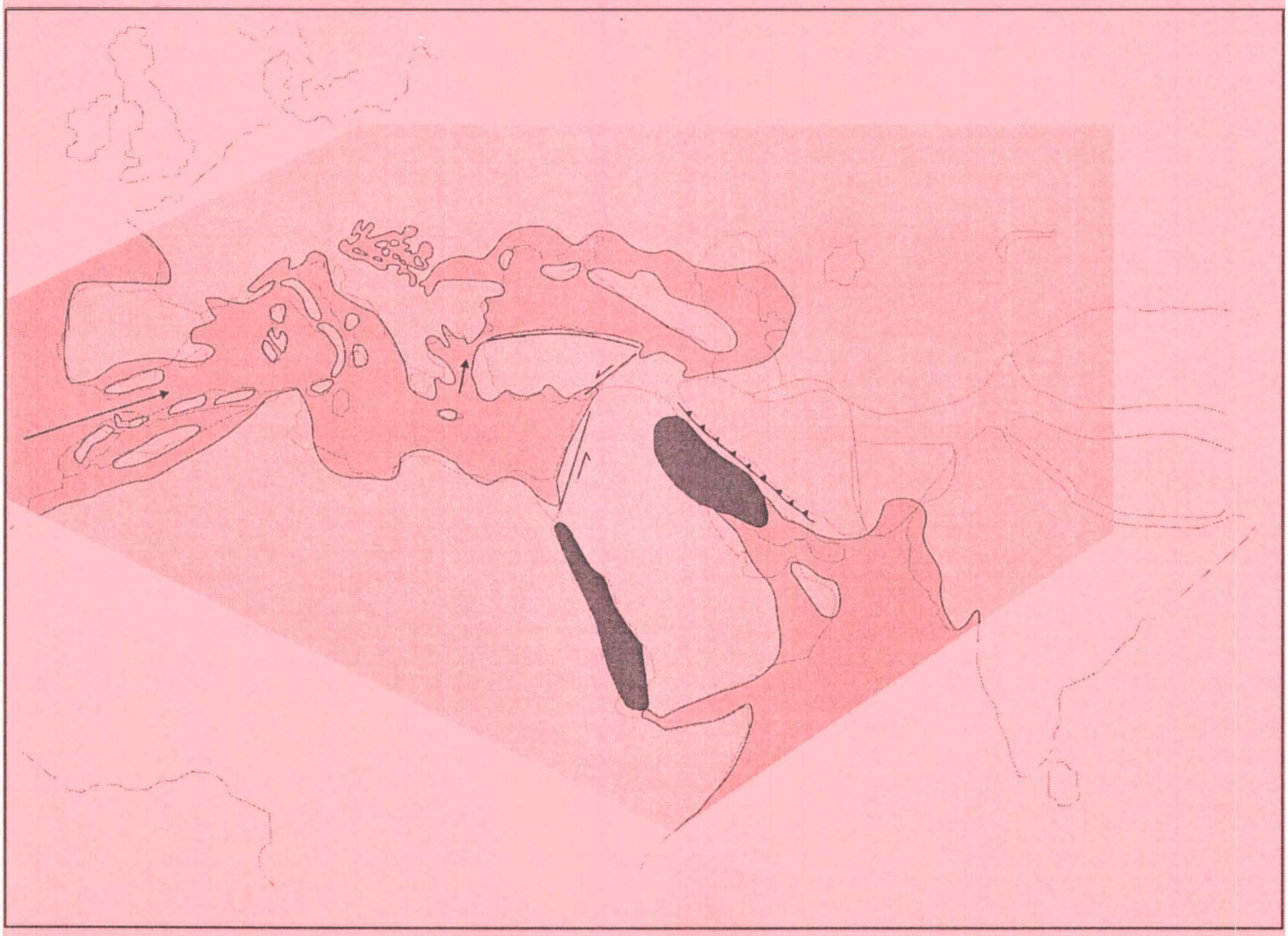
EEDEN

Environmental and Ecosystem Dynamics of the Eurasian Neogene

Stratigraphy & Paleogeography

Workshop 15. - 18. 3. 2001
Graz, Austria



**Berichte
des Institutes für Geologie und Paläontologie
der Karl-Franzens-Universität Graz, Österreich**

Band 4 **Graz, Nov. 2001**

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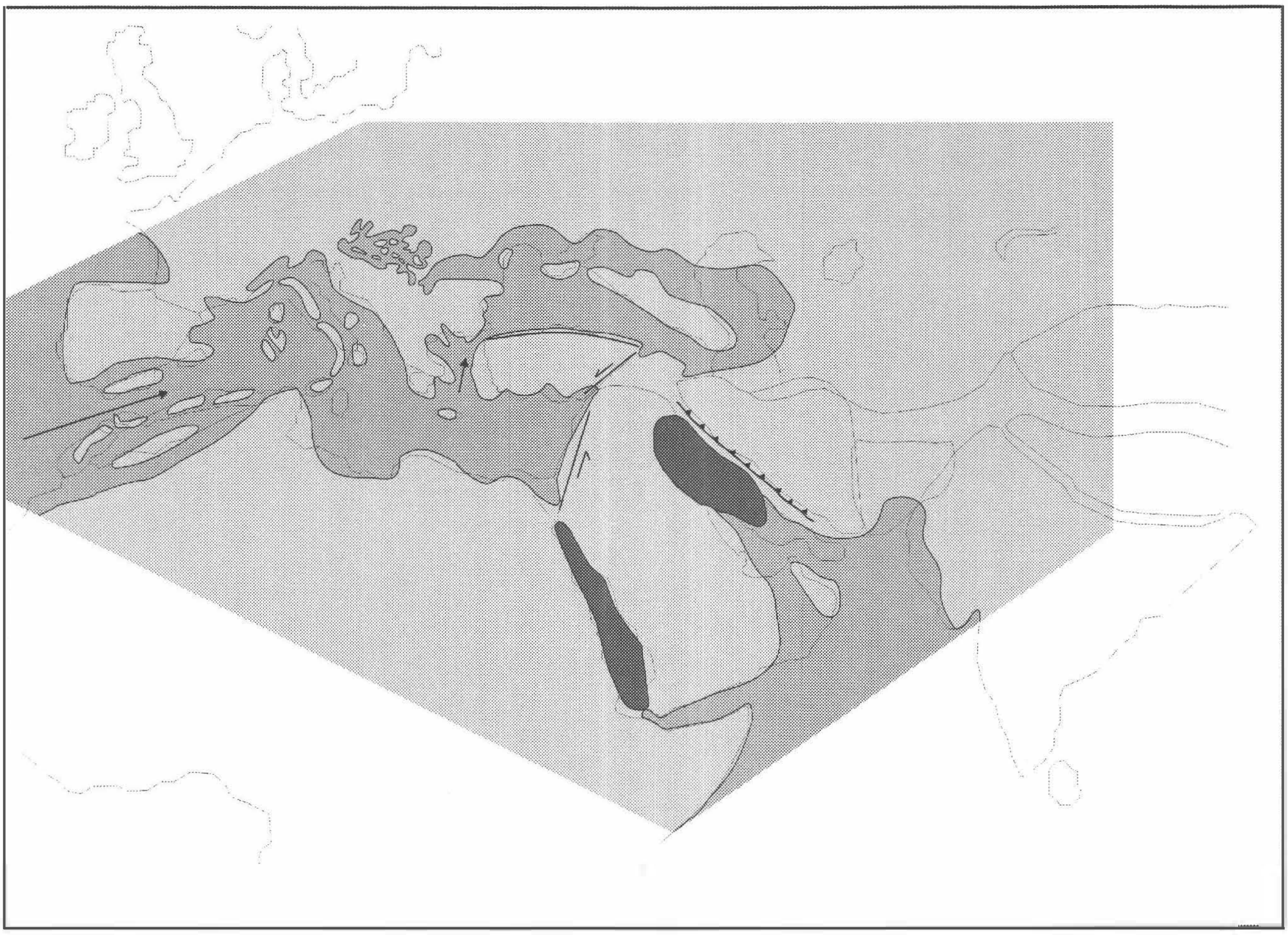

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Preface

The EEDEN programme was initiated by the European Science Foundation to analyse the response of terrestrial ecosystems to environmental changes during selected time slices in the Neogene. Although 3 fairly well-known "high-resolution" time intervals have been chosen (HRI 1: 7 – 4 Ma, HRI 2: 12 – 8.5 Ma, HRI 3: 17 – 14 Ma) for this multidisciplinary study, time resolution and stratigraphic correlation turned out to be still problematic. The restriction to terrestrial ecosystems was undertaken to enhance knowledge on currently less intensively studied non-marine facies. However, a decoupling of both systems – terrestrial and marine – was not possible since they are strongly interrelated. During the state-of-the-art workshop in Lyon in November 2000 the need of small workgroup meetings on particular topics was realized and one such workshop was dedicated to problems in stratigraphy and paleo(bio)geography, focusing on terrestrial – marine relationships.

This workshop was hosted by the University of Graz, Austria, between March 15 – 18, 2001, and co-sponsored by the European Science Foundation and the Institute for Geology and Palaeontology of Graz University. Seventeen scientists of 10 European countries (Austria, Czekia, Finland, France, Germany, Italy, Russia, Slovakia, Spain, The Netherlands) participated at the workshop and presented 15 topics. Since these presentations reflect the state-of-knowledge on Miocene stratigraphic and paleo(bio)geographic problems we concluded to publish these papers in volume 4 of "Berichte des Institutes für Geologie und Paläontologie der Karl-Franzens-Universität Graz".

The stratigraphic articles cover correlation problems in the marine realm which exist between the Mediterranean and the Atlantic, between the Mediterranean and the Paratethys and inside the Paratethys (IACCARINO, GRIGOROVICH, SNEL et al., GONTSHAROVA). In terrestrial environments mammal chronology (FORTELIUS) and correlation between mammalian biozones and magnetostratigraphy was identified as crucial problem, particularly between Spanish and Paratethys sections (AGUSTÍ, VAN DER MEULEN, DAXNER-HÖCK) but also in the Eastern Mediterranean (SEN). In respect to paleogeography the importance of fish otoliths for this topic is pointed out by BRZOBOHATY. Regional problems in paleogeography are presented by KOVÁČ, SISSINGH, POPOV and RÖGL, whereas MEULENKAMP & SISSINGH refer on the more general aspects of the paleogeographic maps of the Peri-Tethys programme. Since some of the papers are or will be published elsewhere these are documented herein as (extended) abstracts only, whereas other papers present new and very important results, as for example the paleogeographic maps of the Paratethys by POPOV and RÖGL.

Werner E. Piller, Christine Latal
Graz, November 2001

Content

Correlation problems in the marine Mediterranean Neogene

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Studies in the marine Mediterranean focussing on the two older HRI´s, HRI 2 and 3, point out the still existing problems in these high resolution intervals. For some problems solutions are going to be accepted, for others further investigations are needed.

Correlation problems of HRI 2:
1) Diachroneity of *N. acostaensis* FO, which historically defines the Serravallian/Tortonian boundary, and of *P. siakensis* between the Mediterranean and Atlantic (Fig. 1).

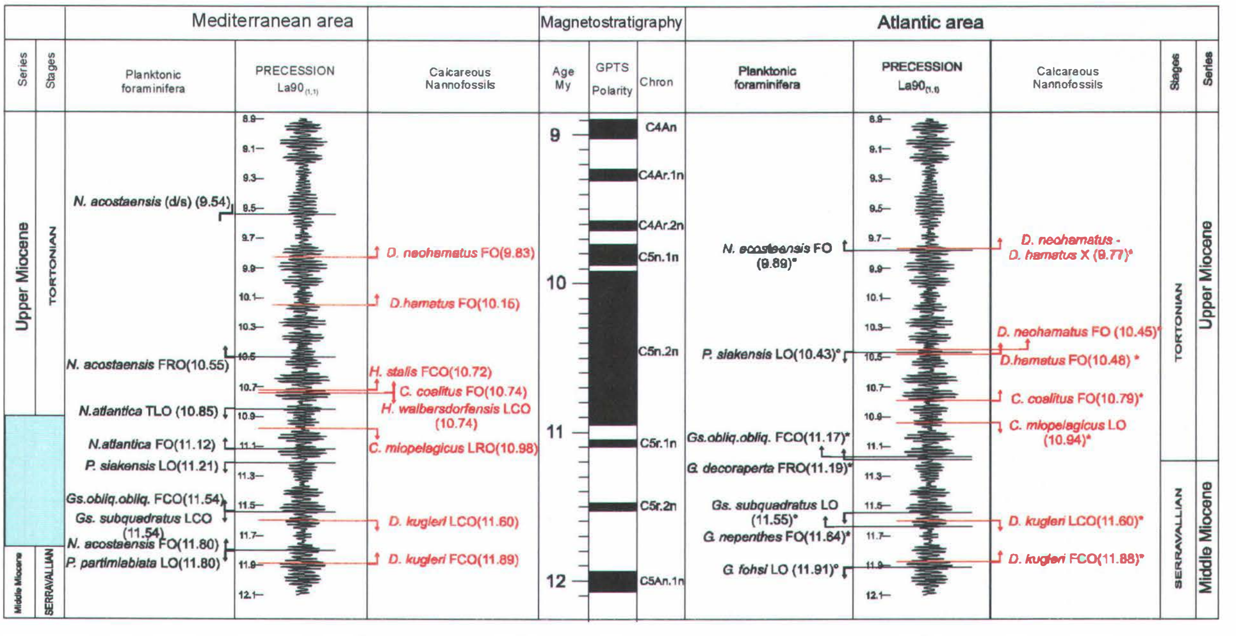

Fig. 1: Comparison of the Mediterranean with the Atlantic area of planktonic foraminifera and calcareous nannofossil events in HRI 2.

2) Lack of magnetostratigraphy.
3) Re-calibration of the Serravallian/Tortonian boundary timing.

Conclusions:
The problem of the Serravallian/Tortonian boundary is close to be solved, although *N. acostaensis* FO and *P. siakensis* LO are diachronous events (Fig. 2), and they cannot be used to define the boundary.

Through the astronomical tuning the LCO of *Globigerinoides subquadratus* (11.54 / 11.55 Ma) seems to be an isochronous event between the Mediterranean and extra-Mediterranean area (Tab. 1, Fig. 3).
The magnetostratigraphic tool is up to now missing and this renders the data as still being in progress.

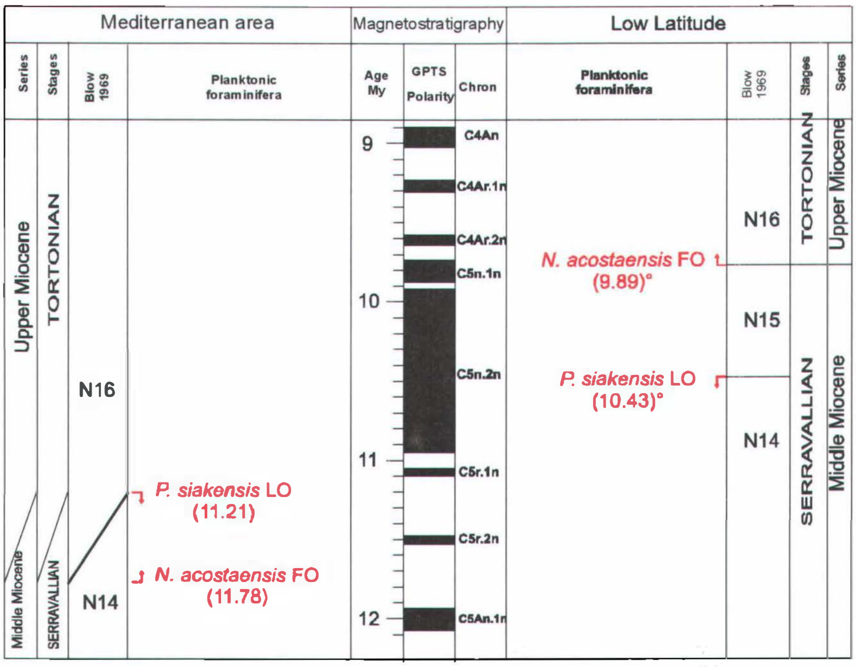

Fig. 2: Datings of LO of *P. siakensis* and FO of *N. acostaensis* in Mediterranean and low latitudes.

HRI 2

EVENTS	*ASTRONOMICAL AGE*	
	MEDITERRANEAN	*ATLANTIC*
planktonic foraminifera		
N. acostaensis (d/s)	9.54	-
N. acostaensis FRO	*10.55*	-
N. atlantica TLO	*10.85*	-
N. atlantica FO	*11.12*	-
G. nephentes FO	-	*11.64**
P. siakensis LO	*11.21*	*10.43**
G. decoraperta FRO	-	*11.19**
G. foshi (s.l.)	-	*11.91**
Gs. subquadratus LCO	*11.54*	*11.55**
Gs. o. obliquus FRO	11.54	11.17
N. acostaensis FO	11.80	9.89*
P. partimlabiata LO	*11.8*	-
calcareous nannoplankton		
D. neohamatus/D. hamatus X	-	*9.77*
D. neohamatus FO	*9.83*	*10.45*
D. hamatus FO	10.15	10.48
H. stalis FCO	*10.72*	-
C. coalitus FO	*10.74*	*10.79*
H. walberdorsfensis LCO	*10.74*	-
C. miopelagicus LRO	*10.98*	*10.94*
D. kugeri LCO	*11.60*	*11.60*
D. kugeri FCO	11.89	11.88

Tab. 1: Astronomical ages of bioevents.

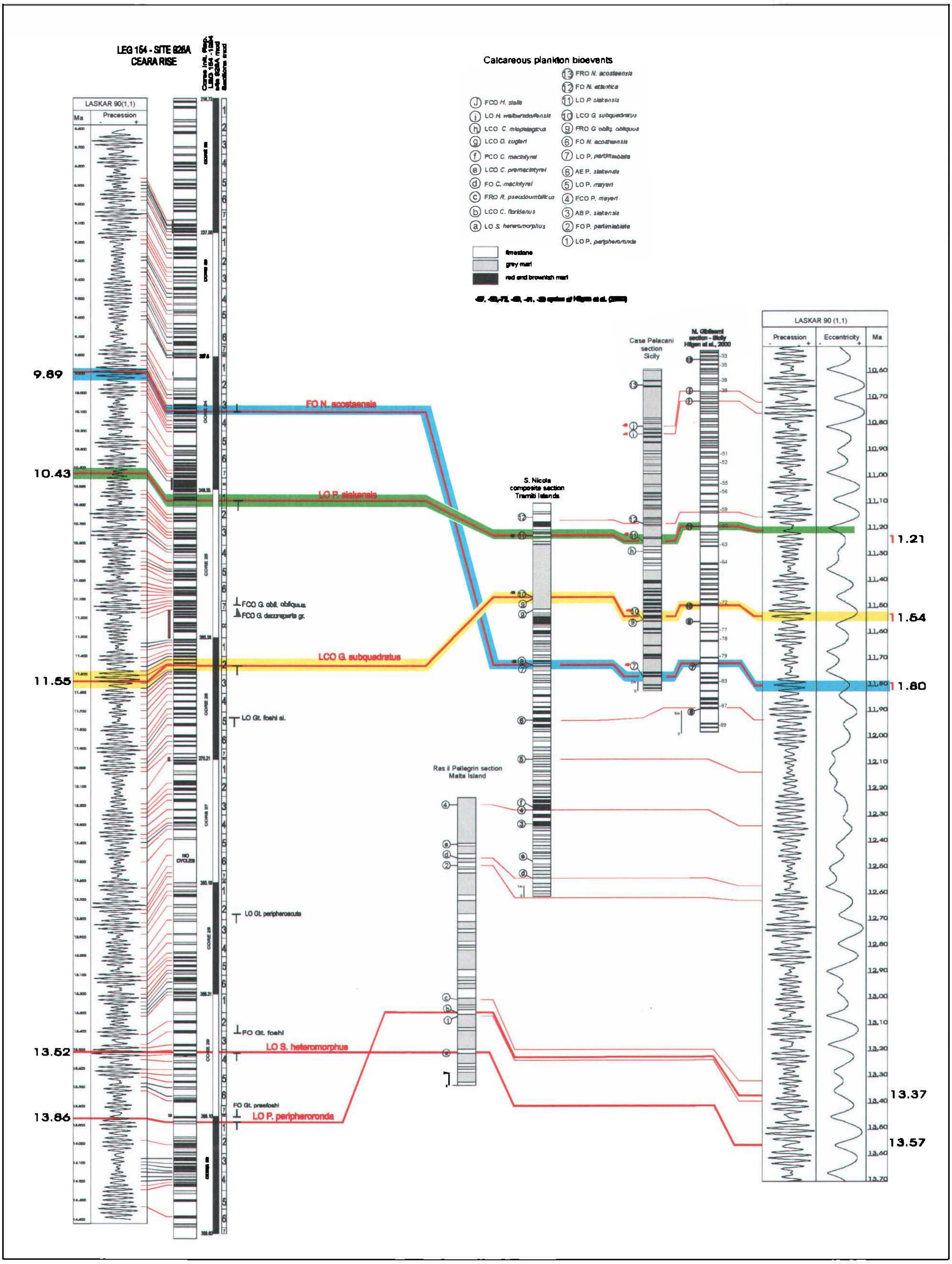

Fig. 3: Correlation of Leg 154 Ceara Rise (TURCO et al. 2001, IACCARINO et al. submitted) with Mediterranean sections focussing on HRI 2.

Correlation problems of HRI 3:
The *Globorotalia peripheroronda* LO and *Sphenolithus heteromorphus* LO are the two events proposed to define the Langhian/Serravallian boundary (RIO et al. 1997) (Fig. 4).

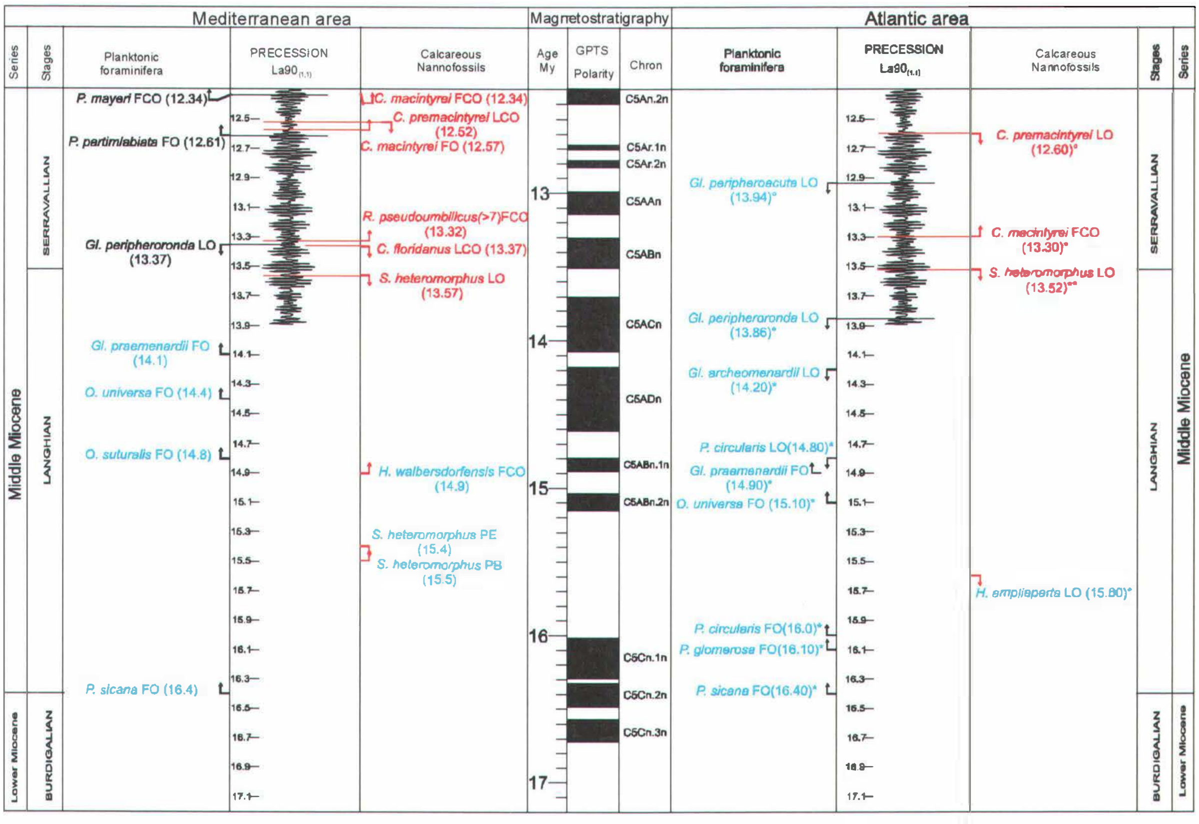

Fig. 4: Comparison of the Mediterranen with the Atlantic area of planktonic foraminifera and calcareous nannofossil events in HRI 3.

Lack of high-resolution integrated stratigraphy (cyclostratigraphy, magnetostratigraphy and calcareous plankton biostratigraphy) in good marine successions encompassing the Langhian/Serravallian and Burdigalian/Langhian boundaries

Conclusions:
The problems are far from being solved.
The LO of *G. peripheroronda* is diachronous between the Mediterranean and extra-Mediterranean area; on the contrary, the LO of *S. heteromorphus* (13.57 / 13.52 Ma) is up to now an almost synchronous event (Fig. 5).

High-resolution integrated stratigraphy (cyclostratigraphy, magnetostratigraphy and plankton biostratigraphy) is fundamental to solve the correlation problems of this time interval.

In the Langhian stratotype (Cessole section - Piedmont Tertiary Basin) all steps from *G. praeorbulina* to *G. orbulina* occur, raising correlation problems with Paratethys sections.

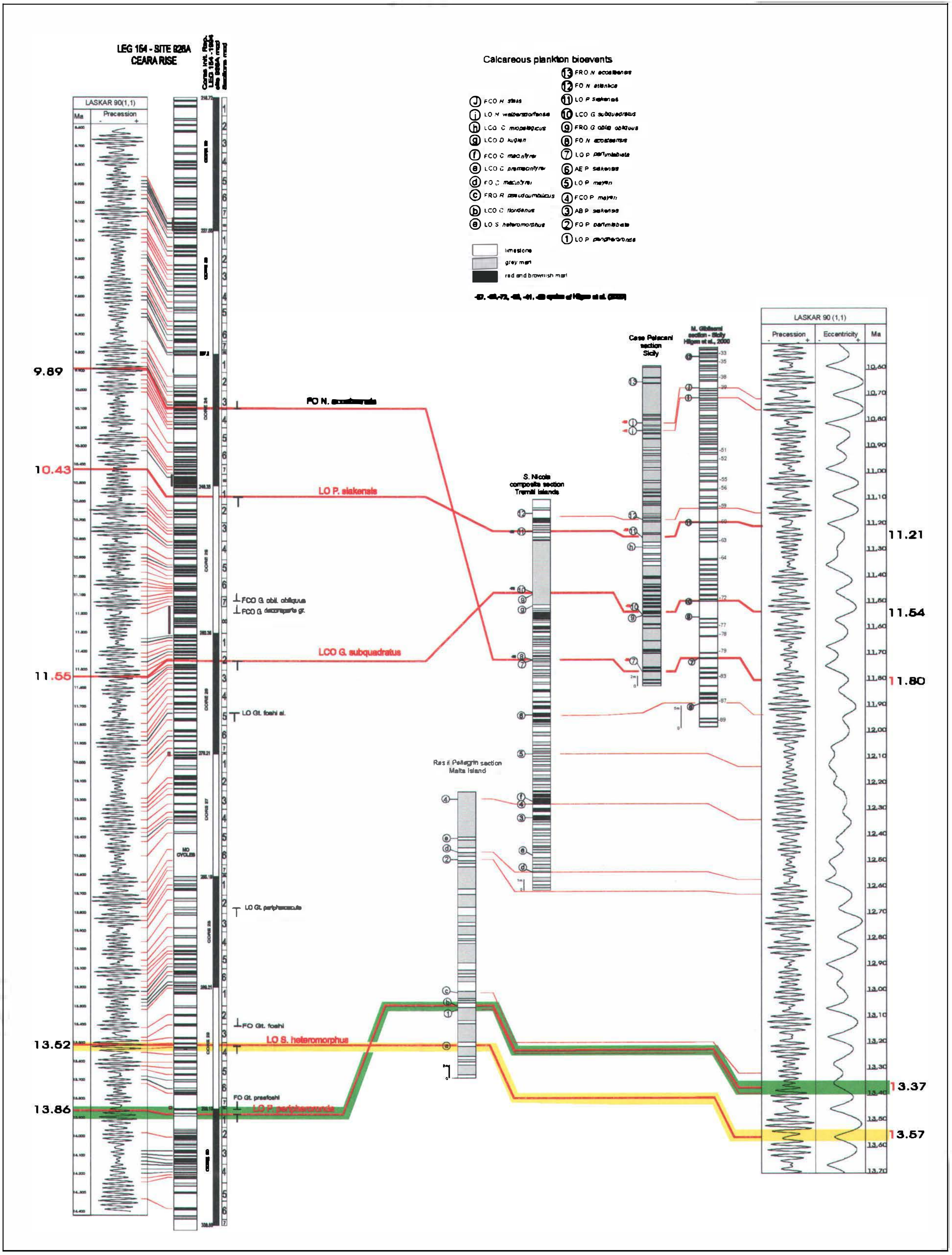

Fig. 5: Correlation of Leg 154 Ceara Rise with Mediterranean sections focussing on HRI 3.

References

IACCARINO, S., BONOMO, S., CARUSO, A., DI STEFANO, A., DI STEFANO, E., FORESI, L.M., LIRER, F., MAZZEI, R., SALVATORINI, G., SPROVIERI, M. & SPROVIERI, R., submitted: Astrochronology of late Middle Miocene Mediterranean sections.

RIO, D., CITA, M.B., IACCARINO, S., GELATI, R. & GNACCOLINI, M., 1997: Langhian, Serravallian, and Tortonian historical stratotypes. – In: MONTANARI, A., ODIN, G.S. & COCCIONI, R., (eds.): Miocene Stratigraphy: an integrated approach, 57-87, Elsevier Science, Amsterdam.

TURCO, E., FORESI, L.M., LIRER, F., IACCARINO, S. & SALVATORINI, G., 2001: Middle Miocene biostratigraphy and paleobiogeography from the Equatorial Atlantic Ocean (Leg 154, Site 926A). - Paleobiogeography and Paleoecology 2001, Intern. Confer. May 31- June2, 2001, Piacenza & Castell´Arquato, Italy.

Mid-Miocene nannoplankton correlation in the Paratethys

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Nannoplankton correlations between Central and Eastern Paratethys were focussing on the two older HRI´s, starting with NN4. Up to NN6 the Central Paratethys had marine conditions. As seen in Figs. 1 and 2 correlation problems between Central and Eastern Paratethys occur in NN5 up to NN8. One main problem is the correlation of NN7, Badenian or Sarmatian in the Central Paratethys. In the presented scheme NN4 represents Karpatian, NN5 Early Badenian, NN6 Late Badenian, NN7 and NN8 are placed into the Sarmatian, and NN9 into Pannonian A.

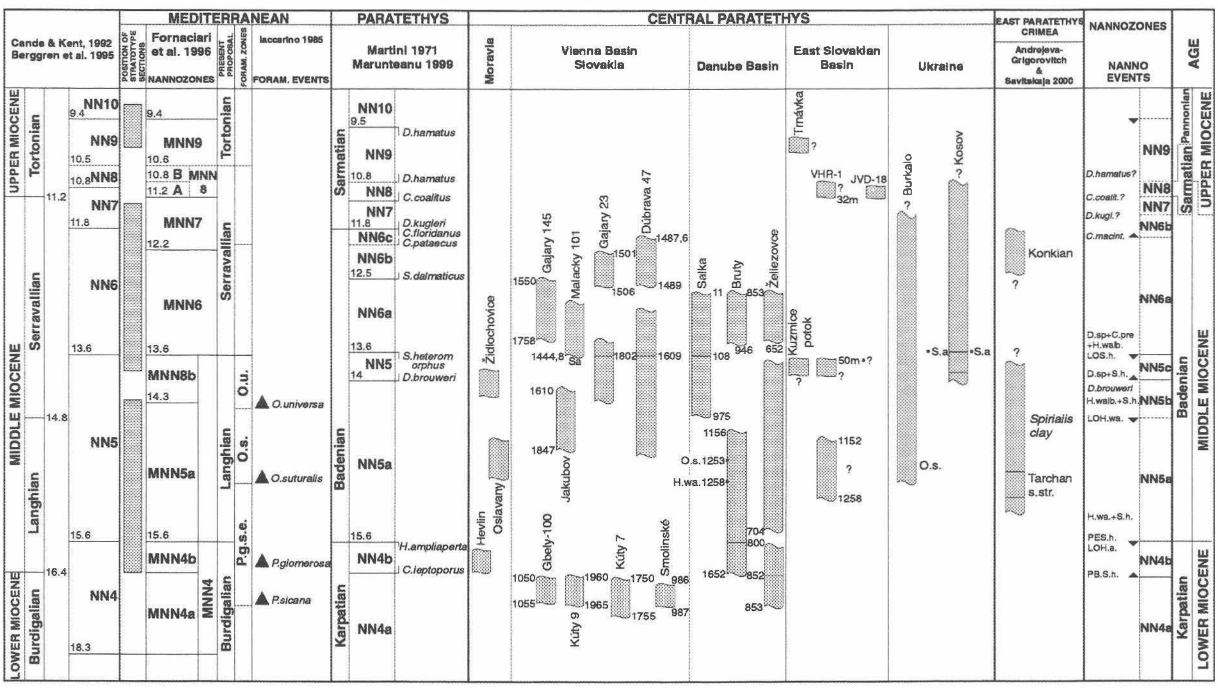

Fig. 1: Compilation of nannofossil zonations of the Mediterranean, Paratethys, Central Paratethys and Eastern Paratethys (after KOVÁČ et al. 2000, HUDÁČKOVÁ 1995, HUDÁČKOVÁ & SLAMKOVÁ 2000, ANDREYEVA-GRIGOROVICH & HALÁSOVÁ 2000).

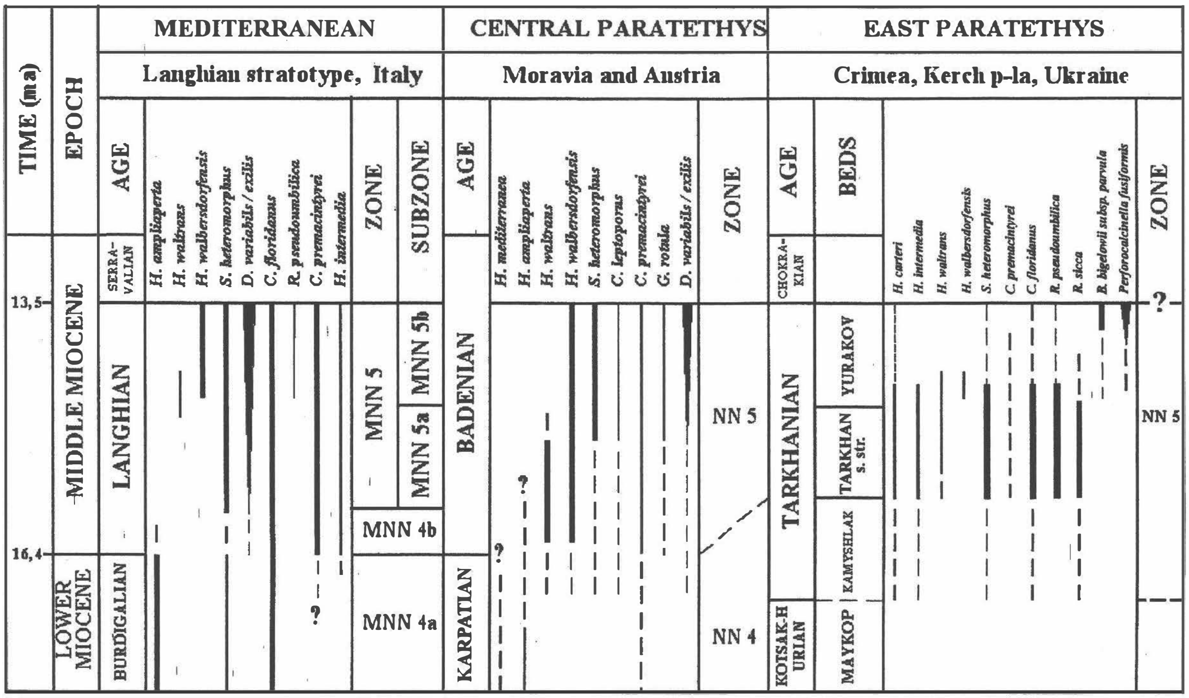

Fig. 2: Comparison of nannoplankton zones and ranges of the most important taxa in the stratotype area of Tarkhanian deposits of Kerch peninsula (East Paratethys) and Karpatian/Badenian sediments in Moravia and Lower Austria (Central Paratethys) (In: SVABENICKA & CTYROKA 1999) and Langhian stratotype area in Italy (Mediterranean area) (In: FORNACIARI et al. 1996).

Nannoplankton association of the NN4a zone (*Heliocosphaera ampliaperta-Sphenolithus heteromorphus*):
Calcidiscus leptoporus, Reticulofenestra pseudoumbilicus, Helicosphaera mediterranea, Calcidiscus premacintyrei, Orthorhabdus serratus, Helicosphaera ampliaperta, Helicosphaera scissura

Foraminiferal association of the NN4a zone:
Uvigerina graciliformis, Uvigerina accumminata, Uvigerina pygmoides, Pappina primiformis, Pappina breviformis, Bolivina hebes, Reussella spinulosa, Valvulineria complanata, Sphaeroidina bulloides, Cibicides ungerianus, Heterolepa dutemplei, Nonion commune, Ammonia sp., *Pararotalia aculeata, Protoelphidium* spp., *Elphidiella minuta* (HUDÁČKOVÁ et al. 1997)

Nannoplankton association of the NN4b zone (*Helicosphaera ampliaperta*-paraacme *Sphenolithus heteromorphus*):
Calcidiscus leptoporus, Calcidiscus premacintyrei, Reticulofenestra pseudoumbilicus, Helicosphaera mediterranea, Helicosphaera ampliaperta, Helicosphaera scissura, Helicosphaera carteri, Helicosphaera walbersdorfensis, Helicosphaera vedderi, Helicosphaera intermedia, Orthorhabdulus serratus, Umbilicosphaera rotula

Nannoplankton association of the NN5a zone (*Sphenolithus heteromorphus-Helicosphaera waltrans*):
Calcidiscus leptoporus, Calcidiscus premacintyrei, Coccolithus miopelagicus, Coronocyclus nitescens, Helicosphaera waltrans, Helicosphaera walbersdorfensis, Helicosphaera carteri, Reticulofenestra pseuoumbilicus, Rhabdosphaera sicca, Discoaster exilis

Nannoplankton association of the NN5b zone (*Sphenolithus heteromorphus-Helicosphaera walbersdorfensis*):
Calcidiscus leptoporus, Calcidiscus premacintyrei, Discoaster exilis, Discoaster deflandrei, Helicosphaera walbersdorfensis, Helicosphaera carteri, Cyclicargolithus floridanus, Orthorhabdulus serratus, Holococcolithus macroporus, Rhabdosphaera sicca, Sphenolithus abies, Sphenolithus moriformis, Coccolithus miopelagicus, Pontosphaera multipora, Hayella challengeri

Nannoplankton association of the NN5c zone (*Sphenolithus heteromorphus-Discoaster brouweri*):
Calcidiscus leptoporus, Calcidiscus premacintyrei, Discoaster brouweri, Discoaster petaliformis, Discoaster exilis, Helicosphaera walbersdorfensis, Helicosphaera carteri, Cyclicargolithus floridanus, Holococcolithus macroporus, Rhabdosphaera sicca, Sphenolithus abies, Sphenolithus moriformis, Coccolithus miopelagicus, Pontosphaera multipora, Triquetrorhabdulus rugosus

Nannoplankton association of the NN6 zone (*Discoaster exilis*):
Calcidiscus leptoporus, Calcidiscus premacintyrei, Sphenolithus abies, Sphenolithus moriformis, Discoaster exilis, Discoaster brouweri, Discoaster variabilis, Discoaster formosus, Discoaster challengeri, Reticulofenestra pseudoumbilicus, Rhabdosphaera sicca, Pontosphaera multipora, Triquetrorhabdulus rioi, Triquetrorhabdulus rugosus, Braarudosphaera bigelowii (small forms)

Nannoplankton association of the NN8 zone (*Catinaster coalitus*):
Calcidiscus leptoporus, Calcidiscus premacintyrei, Sphenolithus abies, Sphenolithus moriformis, Reticulofenestra pseudoumbilicus, Rhabdosphaera sicca, Pontosphaera multipora, Braarudosphaera bigelowii (small forms), *Helicosphaera carteri, Helicosphaera intermedia, Scyphosphaera lagena, Umbilicosphaera rotula, Umbilicosphaera jafari, Syracosphaera pulchra, Calciosolenia murrayi*

Nannoplankton association of the NN9 zone (*Discoaster hamatus*):
Discoaster hamatus, Calcidiscus leptoporus, Calcidiscus premacintyrei, Sphenolithus abies, Sphenolithus moriformis, Reticulofenestra pseudoumbilicus, Reticulofenestra aff. *productella, Rhabdosphaera sicca, Pontosphaera multipora, Braarudosphaera bigelowii* (small forms), *Helicosphaera carteri, Helicosphaera intermedia, Helicosphaera* cf. *orientalis, Scyphosphaera lagena, Umbilicosphaera rotula, Umbilicosphaera jafari, Syracosphaera pulchra, Calciosolenia murrayi*

References

ANDREYEVA-GRIGOROVIČ, A. & HALÁSOVÁ, E., 2000: Calcareous Nannofossils biostratigraphy of the Early Miocene sediments of the Vienna Basin NE part (Slovakia). - Slovak Geol. Mag., 6, 2-3, 101-105, Bratislava.

BERGGREN, W.A., KENT, D.V., SWISHER, C.C. & AUBRY, M.-P., 1995: A revised Cenozoic Geochronology and Chronostratigraphy. - In: BERGGREN, W.A., KENT, D.V. & HARDENBOL, J., (eds.): Geochronology, Time Scales and Global Stratigraphic Correlations: A Unified Temporal Framework for a Historical Geology. - SEPM Special. Publ., 54, 129-212, Tulsa.

FORNACIARI, E., DI STEFANO, A., RIO D. & NEGRI, A., 1996: Middle Miocene quantative calcareous nannofossil biostratigraphy in the Mediterranean region. - Micropaleontology, 42/1, 37-63, New York.

HUDÁČKOVÁ, N., 1995: Ecotype variability of genus *Ammonia* BRUNNICH 1772 in Neogene of paratethys and their paleoecological significance. - Mineralia Slov., 27, 133-144, Bratislava.
HUDÁČKOVÁ, N., 1995: Dinoflagellata from the Pannonian sediments of the NW part of Vienna basin. – Rom. Journ. Stratigr., 76/7, Bucharest.
HUDÁČKOVÁ, N. & SLAMKOVA, M., 2000: Paleoecological reconstruction of the Pannonian sediments of the NW part of the Vienna Basin (Slovak part). - Mineralia Slov., 32, 439-441, Bratislava.
KOVÁČ, M., HUDÁČKOVÁ, N. & BARÁTH, I. 2000: Paleogeography, Geodynamics & Eustacy in the Carpathian – Pannonian region during the Miocene. - EEDEN, Environments and Ecosystem Dynamics of the Eurasian Neogene, 29-38, Lyon.
MARTINI, E., 1971: Standard Tertiary and Quaternary calcareous nannoplankton zonation. - In: Proceeding of 2nd planktonic conference 1970, 739-785, Roma.
SABOL, M., 2000: Neogene Carnivores of Slovakia. - Slovak Geol. Mag., 6/2-3, 124-126, Bratislava.

The position of the Pontian relative to Mediterranean Stages

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Accurate datings of the lower and upper limits of the Pontian stage are of crucial importance for palaeogeographical and palaeoenvironmental reconstructions pertaining to the latest Miocene to Early Pliocene High Resolution Interval 1 (~ 7 - 4 Ma) of the EEDEN Programme. New magnetostratigraphic as well as calcareous nannoplankton data inferred from the upper Maeotian to Dacian records of the Dacic Basin in Romania allow high-resolution correlations with Tortonian, Messinian and Lower Pliocene successions of the Mediterranean. The results demonstrate that the Maeotian – Pontian boundary should be placed at ~ 6.15 Myr, while the Pontian – Dacian boundary has an age of about 5.30 Myr (SNEL et al. in prep.). The occurrences of interbeds with marine calcareous nannoplankton assemblages in upper Maeotian and Pontian deposits of the Eastern Paratethys reflect ephemeral marine ingressions from the Mediterranean, probably through the Northern Aegean Corridor.

Tarkhanian and Chokrakian of the Eastern Paratethys: state of knowledge and correlation

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The stratigraphic extent of the Tarkhanian and Chokrakian varies widely in the opinion of different scientists. We include all "*spirialis*"-clays of the hypostratotype into the Tarkhanian and place the boundary at their top. This level of faunistic change coincides with the structural and facial reorganisation of the basin and can be traced all over its territory.

A series of sections extends from Crimea through Pre-Causasus to the West Georgian Dzhgali locality in the Megrelian Depression (Figs. 1, 2). Tarkhanian deposits are usually dominated by clay; sands and limestones, often with bioherms, and only subordinate clay characterise the Chokrakian. Karaganian deposits represent mostly sands and clays, sometimes with stromatolites. The thickness of Tarkhanian sediments varies from 120 m to 450 m (in depressions), that of Chokrakian reaches up to 700 m.

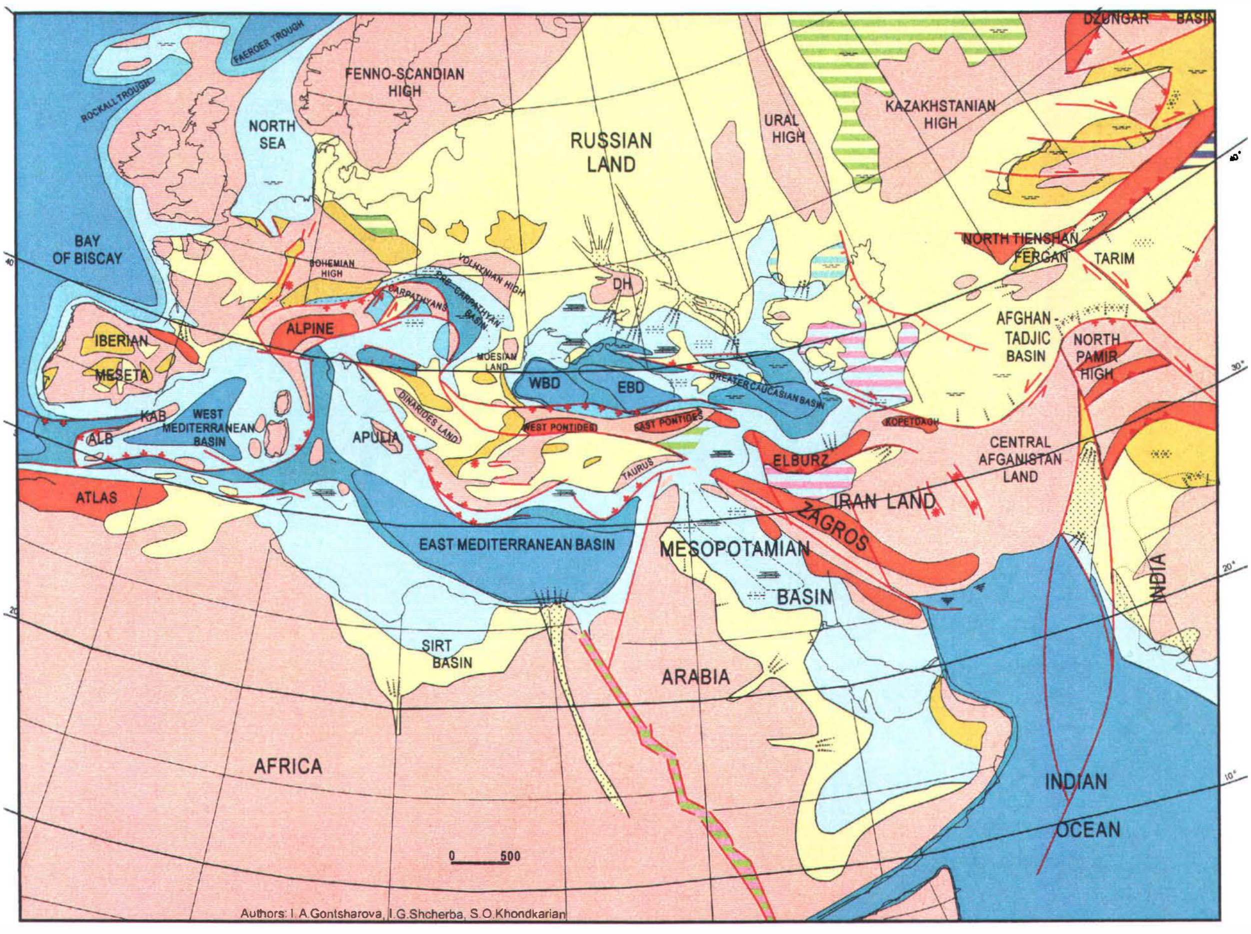


Fig. 1: Paleogeography of the Mediterranean Fold Belt in the beginning of the Middle Miocene (Chokrakian - Early Badenian - Langhian). Authors: GONCHAROVA, SHCHERBA, KHONDKARIAN.

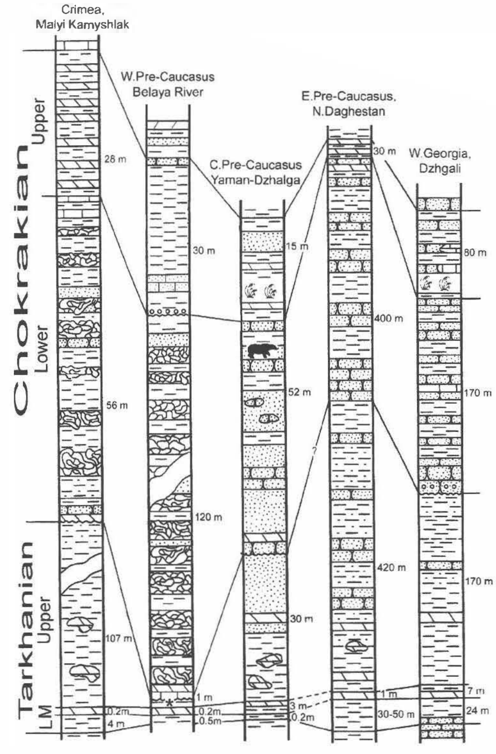


Fig. 2: Correlation of sections extending from Crimea through Pre-Caucasus, and also the West Georgian section at Dzhgali in the Megrelian Depression (modified after GONCHAROVA 1989).

Intra-basin subdivision is based on well known benthic foraminifera and molluscs. A benthic foraminiferan zonal scheme was developed by BOGDANOWICZ (1965, 1974) for the Tarkhanian and Chokrakian (Fig. 3). The zones largely coincide with data on molluscs (BOGDANOWICZ & GONCHAROVA 1976).

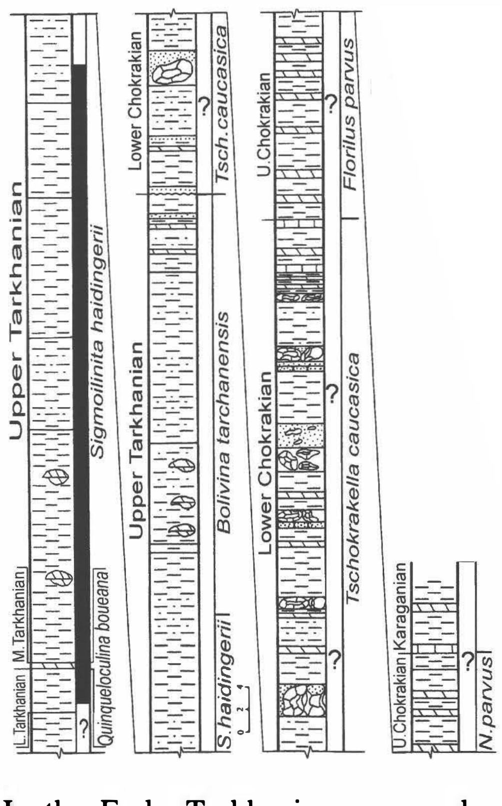


Fig. 3: Hypostratotype of Tarkhanian and Chokrakian Regional Stages (Crimea, Kerch Peninsula, Malyi Kamyshlak) after GONCHAROVA (1989), showing additionally benthic foram zones after BOGDANOWICZ (1965, 1974) and paleomagnetic data after PEVZNER (pers. comm.).

In the Early Tarkhanian a normal oxygen regime was restored and a marine fauna re-appeared. Few endemic brackish elements (*Rzehakia dubiosa* HOERNES = *R. socialis* RZEHAK, *Congeria nucleolus* RZEHAK, *Saccamina zuramakensis* BOGDANOWICZ), inherited from the

Kozakhurian, persisted locally into the lower Upper Tarkhanian. A similar persistence occurs in brackish facies of the Karpatian. The fauna reaches its climax in the Middle Tarkhanian and experiences impoverishment during the Late Tarkhanian. In the hypostratotype this starts abruptly at 11.5 m above the base and becomes more gradual upsection. ANANIASHVILI (1999) also reports an impoverishment of molluscs at the same level in Skelya section. The Early Chokrakian is marked by a distinct enrichment of the fauna, which, however, nearly disappeared in the Late Chokrakian. The Karaganian is characterised by a diversification of a fauna which is endemic to the Eastern Paratethys. The benthic foraminiferan zones are unfortunately based mainly on endemic species and cannot easily be correlated with the zones of the Central Paratethys.

Biostratigraphic data

Planktic foraminifera are low diverse in the Tarkhanian. The prevailing taxon is *Globigerina tarchanensis* SUBBOTINA & CHUTZ. The most recent and complete data are reported by TROFIMOVICH (in ANANIASHVILI 1999) from the Skela section. This is located at the eastern wing of the anticline where the hypostratotype (Fig. 4) crops out in the other wing.

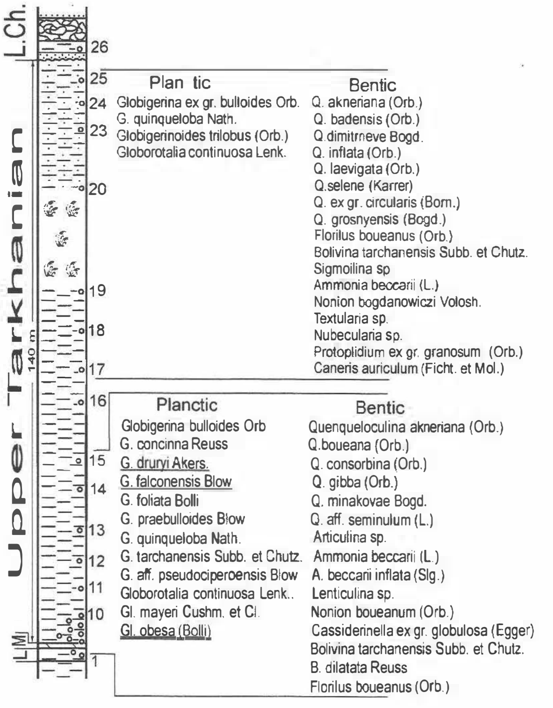


Fig. 4: Foraminifera identified by TROFIMOVICH (in ANANIASHVILI 1999) in Skela section.

In the lower part of the section (42 m thick, samples 2 – 15) 12 species are recorded, the upper part (72 m thick, samples 17 – 25) brought forth 4 species. No precise data on the individual samples are given and no correlation of the two assemblages with a biozonal scheme is presented by the author. The lower assemblage, however, includes 2 species which are characteristic for the Badenian and one species which was not found above the Karpatian till now (according to CICHA et al. 1998). IVANOVA (1999) and BARG & IVANOVA (2000), however, report *Globigerioides bisphaericus* and *Globoquadrina dehiscens* from the Middle and Upper Tarkhanian in bore-holes in the Alma Depression in Crimea (from deposits of 4 m and 0.6 – 4.5 m thickness). They attribute these deposits to the zone of *Globigerinatella insueta*. No planktic foraminifera are recorded in the Chokrakian.

Nannoplankton data of the Tarkhanian are contradictory in respect to biostratigraphic zonation ANDREYEVA-GRIGOROVICH & SAVYTSKAYA (2000) place the entire Tarkhanian into zone NN5, KONENKOVA & BOGDANOVICH (1994) put the NN4/NN5 boundary in the lower part of the Upper Tarkhanian 1.5 m above the marl and IVANOVA et al. (1998) and BARG &

IVANOVA (2000) 5 m above the marl. The Chokrakian deposits are poor in nannoplankton, however, BOGDANOVICH (in BARG 1993) identified still zone NN5 in the overlying Karaganian. In addition, the radiolarian horizon, above the Karaganian, can be correlated with the Welician.

Some interesting results are presented by the first studies of dinocysts in the Eastern Paratethys. In the lower Upper Tarkhanian ZAPOROZHETS (1999) identified *Tuberculodinium vancampoae*, index of the Lower Miocene Subzone VII b of DA COSTA & DOWNIE (1979), *Hystrichosphaeropsis obscura* and *Lingulodinium machaerophorus*. This assemblage can be correlated with the Karpatian and upper part of the Burdigalian, respectively (Tab. 4).

The diatoms *Coscinodiscus grunowii* PANTIC and *Coscinodiscus* (or rather *Cestodiscus* - RADIONOVA 1991) *stokesianus* GREW. from NE Bulgaria (TEMNIKOVA-TOPALOVA & KOZYRENKO 1982) indicate similarities to both the Karpatian *Raphidodiscus marylandicus* – zone and the Lower Badenian diatom assemblage. However, the Chokrakian content considered in this study is not clear. To my knowledge, from other Chokrakian deposits diatoms are known but not studied.

Pteropods (planktic gastropods) have never been specifically studied in the Eastern Paratethys. They were only identified incidentally by various authors (Table 1). Their taxonomic position or stratigraphic range have never been evaluated. The six identified species were assigned to the genus *Limacina*, however, without detailed taxonomic study. The only exception is the identification of *L. valvatina* and *L. andrussovi* by JANSSEN (1984), their record, however, is problematic: *L. valvatina* was sampled in the talus at Cape Tarkhan and originates from Tarkhanian – Chokrakian beds, *L. andrussovi* was found in gypsum bearing sandy limestones of Cape Kop-Kocheghen and belongs probably to Konkian or Karaganian.

<table>
<tr><th rowspan="3"></th><th colspan="7">Eastern Paratethys</th><th colspan="4">Central Paratethys</th></tr>
<tr><th colspan="3">Tarkhanian</th><th colspan="2">Chokrakian</th><th rowspan="2">Konkian</th><th rowspan="2">Karpatian</th><th colspan="3">Badenian</th></tr>
<tr><th>L</th><th>M</th><th>U</th><th>L</th><th>U</th><th>Moravian</th><th>Welician</th><th>Kosovian</th></tr>
<tr><td>L. andrussovi andrussovi (Kittl)</td><td></td><td></td><td></td><td></td><td></td><td>+ (AJ)</td><td></td><td>?</td><td>+ (G)</td><td></td></tr>
<tr><td>L. andrussovi tschokrakensis (Zh.)</td><td></td><td></td><td>+(Zh)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>L. konkensis (Zh.)</td><td></td><td></td><td></td><td></td><td></td><td>+ (LI)</td><td></td><td></td><td></td><td></td></tr>
<tr><td>L. nucleata (Zh.)</td><td></td><td></td><td>+(LI)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>L. subtarchanensis (Zh.)</td><td></td><td>+(Zh)</td><td></td><td>+ (LI)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>L. tarchanensis (Kittl)</td><td>+(MN)</td><td>+(MN)</td><td>+(NT)</td><td>+ (Zh)</td><td></td><td>+ (AJ)</td><td>+ (G)</td><td>+ (G)</td><td></td><td></td></tr>
<tr><td>L. valvatina (Reuss)</td><td colspan="4">+ (AJ)</td><td></td><td></td><td></td><td>+ (BH)</td><td>+ (BH)</td><td>+ (BH)</td></tr>
</table>

Tab. 1: Distribution of pteropods (*Limacina*), found in the upper Lower - lower Middle Miocene of Eastern Paratethys [for the Central Paratethys, data for Austria, Poland and Hungary are after JANSSEN (1984, 1990), BOHN-HAVAS & ZORN (1995); for Romania after GHEORGIAN et al. (1966); Identfication by: JANSSEN (1984), BOHN-HAVAS & ZORN (1995), GHEORGIAN et al.(1966)], ILJINA in GONTSHAROVA (1989), NOSSOVSKY et al. (1976, 1984), ZHIZHCHENKO (1959). In the Eastern Paratethys, only the records are used which are properly located in the section (except *L. valvatina*).

Tarkhanian and Chokrakian bivalves are well studied (Table 2) and nearly all recorded species (92 of the Tarkhanian, 71 of the Chokrakian) have been revised. Both faunas are equally similar to the Karpatian and Badenian: 54% of the Tarkhanian and 52% of the Chokrakian fauna correspond with that of the Badenian; correspondence with the Karpatian fauna is 35% and 31%. All these values are lower than those between the Karpatian and Badenian (63%). For the Tarkhanian, Chokrakian and Badenian the data are based on GONCHAROVA (1989) and STUDENCKA et al. (1998). The preliminary list of Karpatian bivalves is based on CICHA et al. (1967) and PAPP et al. (1973), on studies of Cepreghy-Meznerics and personal studies of collections at the Hungarian Natural History Museum in Budapest and at the Institute of Palaeontology, University of Vienna. Because of the incomplete knowledge of Karpatian bivalves, these data are very preliminary. In particular, as our study of Badenian bivalves does not include clayey facies, which is, however, very important for the Karpatian. Nevertheless it is obvious that Tarkhanian and Chokrakian faunas are very similar to those of the Karpatian and Badenian. Unfortunately, bivalve data do not allow intrabasinal stratigraphic subdivision. Even pectinids, accurate biostratigraphic tools in the Central Paratethys, are of no help. Six pectinid species occur in the Tarkhanian and Chokrakian, two of which are endemic for the Eastern Paratethys. *L. corneus denudatus* occurs in the Lower, Middle and Upper Tarkhanian and is considered to be characteristic for the lower part of the *Flabellipecten besseri* zone (Lower Badenian) of Poland and Ukraina (STUDENCKA 1999). It is, however, also found in the Egerian of Hungary as well as in the Ottnangian (PAPP et al. 1973) and Karpatian (CICHA et al. 1967). More indicative is the Paratethyan endemic *Palliolium bittneri* (TOULA) in Sartaganian beds of Konka, which characterizes the upper subzone of *F. besseri* zone (Upper Badenian).

	number of species	species (%) in common to:	
		Karpatian	Badenian (343 spp.)
Tarkhanian	92	35	54
Chokrakian	71	31	52
Karpatian	187	—	63

Tab. 2: Bivalvian statistics.

According to ILJINA (1993), Tarkhanian benthic gastropods are, like bivalves, more similar to that of the Badenian than to the Karpatian ones. The Chokrakian gastropod associations are quite different due to changed basin connections and coincidence to Karpatian and Badenian gastropods is low.

The mammals of the upper Lower Chokrakian locality Belomechetka in the Western Pre-Caucasus (Table 3) attributed to Zone MN5 by GABUNIA (in MURATOV & NEVESSKAYA 1986) and VISLOBOKOVA (1990), to Zone MN6 by AGADZHANYAN (in MURATOV & NEVESSKAYA 1986), and to the upper MN5 – lower MN6 by LOPATIN (pers. comm.). The fauna needs, however, a taxonomic revision. Younger mammals (Tarkhanian or possibly Lower Chokrakian) of Kyzyl-Bulak (Transkaspa) are referred to MN5 by LOPATIN (pers. comm.), but need also to be revised.

According to AKHMETYEV (1993), the Tarkhanian represents one of the Neogene climatic optima dated into the latest Early Miocene. This is supported by thermophilous mollusc genera (*Pteria, Perna, Isognomon, Atrina, Limaria, Chama, Gibbula, Turritella, Calyptrea*), by a mesophilous subtropical flora, by the presence of sargassan algae, by lunulitiform bryozoans, termites, cockroaches, the thermophilous ant *Dolichoderus*, and a warm water ichthyofauna.

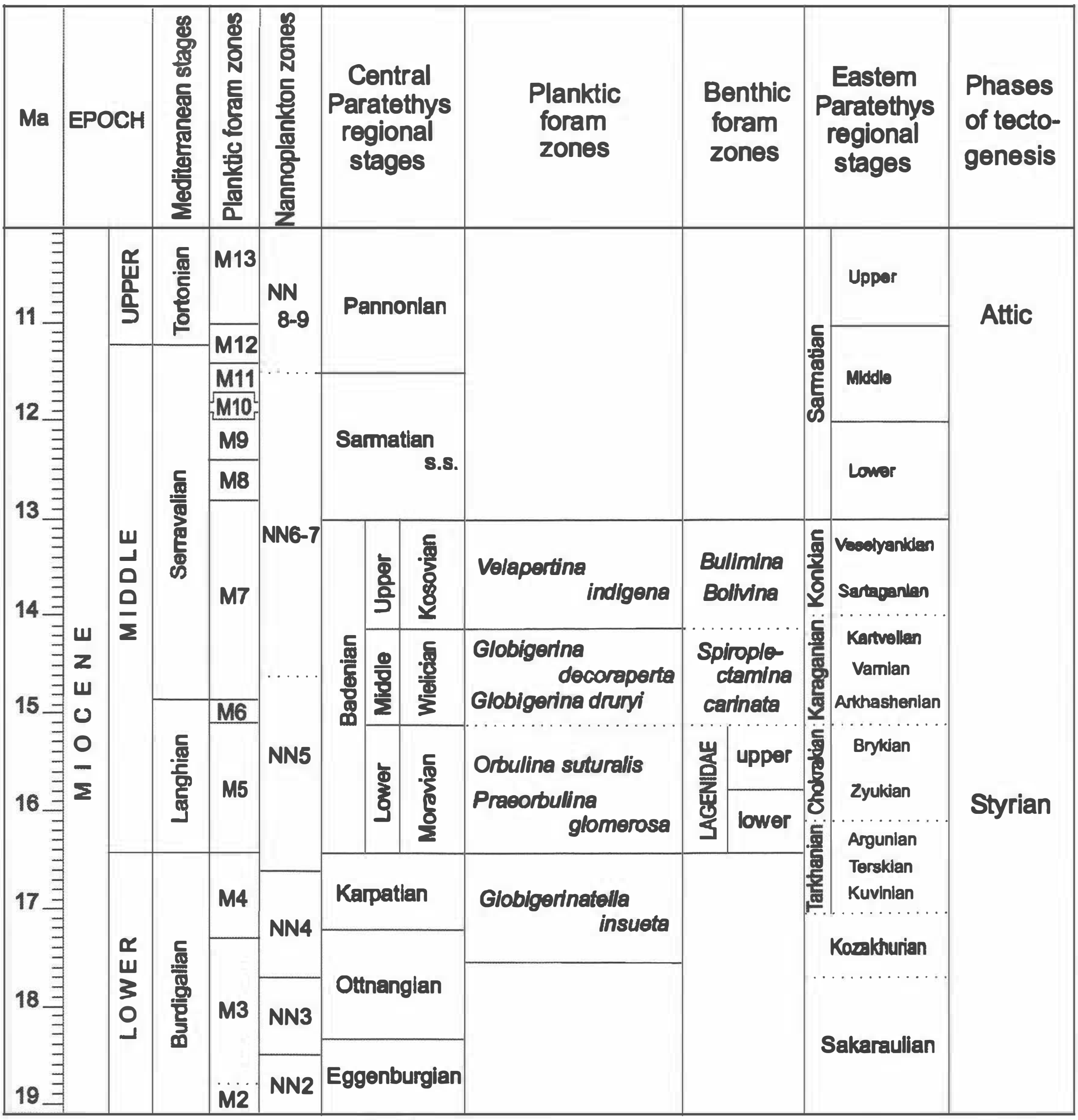
Belomechetka		Kyzylbulak
(Chokrakian in Central Pre-Caucasus; MN5 after GABUNIA, 1986, VISLOBOKOVA pers.comm., MN5-MN6 after LOPATIN pers. comm., MN6 after AGADZANJAN 1986)		(Tarkhanian-L. Chokrakian? In Transcaspian; MN5 after LOPATIN pers. comm.)
Shizogalerix sp.	*Deinotherium* sp.	*Cricetodon* sp.
Amphechinus sp.	*Anchitherium* sp.	*Zygolophodon* sp.
Albanensia sp.	*Paranchitherium karpinski* Borris.	*Anchitherium aurelianense* Cuv.
Mycrodyromys koenigswaldi De Bruijn	*Beliajevina caucasica* (Boriss.)	*Aceratherium* sp.
Protalactaga sp.	*Aceratherium* sp.	*Conohyus* sp.
Cricetodon caucasicus (Argyr.)	*Chilotherium* sp.	*Micromeryx* sp.
C. meieni Freud.	*Caucasotherium efremovi* N. Ver.	*Dicerocerus aralensis* Basch.
Megacricetodon minor (Lart.)	*Bunolistriodon* sp.	*Stephanoceras* sp.
Democricetodon gailladi (Schaub.)	*Kubanochoerus robustus* Gab.	
Deperetomys sp.	*Dorcatherium* sp.	
Bizantinia sp.	*Lagomeryx* sp.	
Fahlbuschia sp.	*Micromeryx* sp.	
Amphicyon caucasicus Gab.	*Dicrocerus belometschetkense* Gab.	
Lapictis sp.	*Paradicrocerus flerovi* Gab.	
Pseudaelurus sp.	*Heteroprox* sp.	
Percrocuta abessalomi Gab.	*Palaeotragus* sp.	
Gomphotherium sp.	*Paratragocerus caucasus* Sok.	
Platybelodon danovi (Boriss.),	*Kubanotragus miocenicus* Sok.	
P. jamandzalgensis Belj. and Gab.	*Hypsodontus mioccenicus* Sok.	
	Orycteropus sp.	

Tab. 3: Mammalia in Belomechetka and Kyzylbulak

Magnetostratigraphic data are contradictory. TRUBIKHIN (1998) records revers polarity for the Tarkhanian and correlates the lower part of the Tarkhanian-Chokrakian interval with Chron C5Br. In contrast, PEVZNER (pers. comm.) found the Tarkhanian to be of normal polarity and correlates this interval with Chron C5Cn (Fig. 3).
According to GONCHAROVA et al. (2001), the Kozakhurian and Tarkhanian are tectonically quiet intervals. This is in contrast to the tectonic reorganisation during the Early Chokrakian as well as the Early Badenian of the Central Paratethys, where the Styrian phase represents an important tectonic event for the development of the Northern Peri-Tethys.

Conclusion

We cannot rely on the contradictory data on planktic foraminifera, calcareous nannoplankton and magnetostratigraphy, as well as on insufficient or not indicative data of benthic foraminifera and diatoms. Hence, we have to deal with data on dinocysts, molluscs (marine fauna with inherited brackish species), climate, and tectonics, which unanimously show that at least the lower Upper Tarkhanian belongs to the Lower Miocene and is therefore below the base of the Badenian (Table 4). The upper part of the Upper Tarkhanian can be correlated to the Badenian (Table 4), although direct evidence for this correlation is missing. The Chokrakian can be correlated to the Lower Badenian (except for its lowermost part). The calcareous nannoplankton (NN5) of the Chokrakian and the abundance of gypsum in the Karaganian makes a correlation of the Chokrakian with the Middle Badenian unlikely. The Konkian most probably correlates to the Upper Badenian (Kosovian).



Tab. 4: Correlation chart of Middle Miocene regional stages of the Central and Eastern Paratethys and Mediterranean stages (GONCHAROVA et al. 2001).

References

ANANIASHVILI, G., 1999: On Biostratygraphy of Middle Miocene sediments of Eastern Paratethys. - Bull. Georgian Acad. Sci., 160/3, 495-497, Tbilisi.

ANDREYEVA-GRIGOROVICH, A.S. & SAVYTSKAYA, N.A., 2000: Nannoplankton of the Tarkhanian deposits of the Kerch Peninsula (Crimea). - Geol. Carpathica. 51/6, 399-406, Bratislava.

AKHMETYEV, M.A., 1993: Fitostratigrafiya kontinental'nykh otlozheniy paleogena i miotsena Vnetropicheskoy Azii [Phytostratigraphy of the non-marine sediments of the Paleogene and Miocene of the Extratropical Asia]. - 140 pp, Moscow, Nauka.

BARG, I.M., 1993: Biostratigrafiya verkhnego kaynozoya Yuzhnoy Ukrainy [Biostratigraphy of the Upper Cenozoic of Southern Ukraine]. - 195 pp, Dniepropertovsk, Dniepropertovsk State University Press.

BARG, I.M. & IVANOVA, T.A., 2000: Stratigraphy and development of the Plain Crimea in Miocene. - Stratigrafiya Geologicheskaya korrelatsiya, 8/3, 83-93 (in Russian).

BOGDANOWICZ, A.K., 1965: Stratigraphic and facial distribution of forams in the Miocene of the Western Pre-Caucasus and problems of their genesis. - Trudy Krasnodarskogo filiala VNIPIneft', 16, 300-351 (in Russian).

BOGDANOWICZ, A.K., 1974: Developmental stages of the foram fauna in the Miocene of North Caucasus and problems of their genesis. - Mem. Bur. rech. geol. et minieres, 78/2, 739-744 (in Russian), Paris.

BOGDANOWICZ, A.K. & GONCHAROVA, I.A., 1976: Environments and changes in composition of forams and bivalve molluscs in the Late Tarkhanian time in the Kerch Peninsula. - Bull. MOIP, Otdel geolog. 51/2, 155-156 (in Russian).

BOHN-HAVAS, M. & ZORN, I., 1993: Biostratigraphic studies on planctonic gastropods from the Tertiary of the Central Paratethys. - Scripta Geol. Spec. Issue 2, 57-66, Leiden.

CICHA, I., SENEŠ J. & TEJKAL, J., 1967: Chronostratigraphie und Neostratotypen – Bd. 1, M3 Karpatien, 312 pp, Bratislava.

CICHA, I., RÖGL, F., RUPP C. & CTYROKA, J., 1998: Oligocene - Miocene foraminifera of the Central Paratethys. - Abhandl. Senckenberg. Naturforsch. Gesellschaft, 549, 325 pp, Frankfurt a. M..

GHEORGHIAN, M., IVA, M., GHEORGHIAN & MIHAELA, 1965/66: Considerations sur le genre Spirialis. - Dari de Seama ale Sedintelor, V. LIII/2, Paleontologie, 1-15.

GONCHAROVA, I.A., 1989: Dvustvorchatyie molluski tarkhanskogo i chokrakskogo basseynov [Bivalve molluscs of the Tarkhanian and Chokrakian basins]. - 200 pp, Trudy Paleontologicheskogo Instituta AN SSSR, 234.

GONCHAROVA, I.A., KHONDKARIAN, S.O. & SHCHERBA, I.G., 2001: The Tarkhanian-Karaganian Stage in development of the Euxinian-Caspian Basin (Eastern Paratethys). Part 1: Tarkhanian - Stratigraphiya. - Geologicheskaya Korrelatsiya, 9/5, 109-123 (in Russian; to be translated into English in Stratigraphy Geol. Correlation 9).

ILJINA, L.B., 1993: Opredelitel' morskikh srednemiotsenovykh gastropod Yugo-Zapadnoy Evrazii [Key for identification of the marine Middle Miocene gastropods of the SW Eurasia]. - 149 pp, Moscow, Nauka Press.

IVANOVA, T.A., 1999: Biostratigrafiya miotsenovykh otlozheniy Ravninnogo Kryma po foraminiferam [Foram based biostratigraphy of the Miocene deposits of the Plain Crimea]. - Abstract of the PhD thesis in geology and mineralogy. Kiev. Inst. Geol. Nauk, 20 pp, NAN Ukrainy.

IVANOVA, T.A., BARG, I. M. & BOGDANOVICH, E.M., 1998: Tarkhanian regional stage of the Plain Crimea. - Izvestiya Vuzov. Geologiya i Razvedka, 1998/2, 44-50 (in Russian).

JANSSEN, A.W., 1984: Type specimens of pteropod species (Mollusca, Gastropoda) described by ROLLE (1961), REUSS (1867) and KITTL (1886), kept in the collection of the Naturhistorisches Museum at Vienna. - Meded. Werkgr. Tert. Kwart. Geol., 21/2, 61-92, Rotterdam.

KONENKOVA, I.D. & BOGDANOVICH, E.M., 1994: Distribution of forams and nanoplancton in the Tarkhanian and Chokrakian deposits of the Malyi Kamyshlak (Kerch Peninsula). - In: Biosphery geologichnego minulogo Ukrainy [Biospheres of the geological past of Ukraine]. - Kiev. Inst. Geol. Nauk, NAN Ukrainy: 95-96 (in Russian).

MURATOV, M.B. & NEVESSKAYA, L.A., (eds.) 1986: Neogenovaya sistema [Neogene System]. - 442 pp, Half-vol. 2, Stratigrafiya SSSR [Stratigraphy of the USSR].

NOSSOVSKY, M.F., BARG, I. M., PISHVANOVA, L.S. & ANDREYEVA-GRIGOROVICH, A.S., 1976: On volume of the Tarkhanian Stage in Southern USSR. - In: Stratigrafiya kaynozoya Severnogo Prichernomorya i Kryma [Stratigraphy of the North Black Sea Region and Crimea]. - Dniepropertovsk, Dniepropertovsk State University Press, 22-31 (in Russian).

NOSSOVSKY, M.F. & BOGDANOVICH, E.M., 1984. On the nanoplancton based correlation of the Tarkhanian Regiostage. - Doklady Acad. Sci. USSR, 275/2, 440-441 (in Russian).

RADIONOVA, E.P., 1991: Stratigrafiya neogena tropicheskoy oblasti Tikhogo okeana po diatomeyam [The diatom based Neogene stratigraphy of the tropic area of the Pacific Ocean]. - 110 pp, Moscow, Nauka Press.

STEININGER, F.F, CTYROKY, P., HÖLZL, O., KOKAY, J., SCHLICKUM, W.R., SCHULTZ, O. & STRAUCH, F., 1973: Die Molluskenfaunen des Ottnangien. - In: PAPP, A., RÖGL, F., SENES, J. (eds.): Chronostratigraphie und Neostratotypen - Bd. 3, M2 Ottnangien, 380-616, Bratislava.

STUDENCKA, B., GONTSHAROVA, I.A. & POPOV, S.V., 1998: The bivalve faunas as a basis for reconstruction of the Middle Miocene history of the Paratethys. - Acta Geol. Polonica, 48/3, 285-342, Warzawa.

TEMNIKOVA-TOPALOVA, D.N. & KOZYRENKO, T.F., 1982: On the diatom algae in the Chokrak deposits of west part of the Eastern Paratethys (NE Bulgaria). - Botanicheskiy Zhurnal, 67, 643-647 (in Russian).

TRUBIKHIN, V.M., 1998: Paleomagnetic scale and stratigraphy of the Neogene-Quaternary deposits of the Paratethys. - In: Opornyie razrezy neogena Vostochnogo Paratetisa (Tamanskiy poluostrov) [Base sections of the Neogene Eastern Paratethys (Taman' Peninsula)]. - Abstract Volume Volgograd & Taman, Volgogradskaya Geologo-Razvedochnaya Ekspeditsiya Ministerstva prirodnykh resursov RF, 13-21 (in Russian).

VISLOBOKOVA, I.A., 1990: Iskopaemyie oleni Evrazii [Fossil deers of Eurasia]. - 207 pp, Trudy Paleontologicheskogo Instituta AN SSSR, 240.

ZHIZHCHENKO, B.P., 1959: Atlas srednemiotsenovoy fauny Severnogo Kavkaza i Kryma [Atlas of the Middle Miocene fauna of North Caucasus and Crimea]. - 386 pp, Moscow, Gosnauchtekhizdat.

ZAPOROZHETS, N.I., 1999: Palinostratigraphy and zonal division of the Middle Eocene - Lower Miocene deposits of Belaya River (NW Pre-Caucasus) after dynocysts. - Stratigraphiya Geologicheskaya Korrelatsiya, 7/2, 61-78 (in Russian).

Defining MN-units and magnetobiostratigraphic correlation of the Spanish sections

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The main problem in the biostratigraphic system of mammalian MN-units is that these units are not well defined and lack strict boundaries, but this system can be enhanced by boundary definitions. In this way, small mammals are an excellent tool to achieve high resolution standards, but they rarely migrate over large distances.
The Spanish Neogene basins include the highest density of large and small mammal localities in Europe, and therefore the highest resolution level may be found there. With the exception of the Messinian, no direct connection existed between Iberia and Africa during the Miocene, and therefore the occurrence of new mammals in Iberia often resulted from a previous route through France and Central Europe.

In Spain the following definitions for MN-zones are proposed (AGUSTÍ et al. 2001); the calibration of the MN boundaries is shown in Figs. 1 and 2.

MN1 (Oligocene-Miocene transition): FAD of *Vasseuromys* in the Ebro basin, where the Oligocene-Miocene boundary was calibrated by magnetostratigraphic correlations. Base: 23.8 Ma, base of chron C6Cn.2n
MN2: FAD of *Andegameryx* and *Amphitragulus* (moschoid artiodactyls).
Among rodents a distinction is only possible by particular stages of evolution of cricetids (*Eucricetodon*) and eomyids (*Ritteneria*). The younger part of this unit is characterized by *Ligerimys* (eomyids), *Pseudaelurus, Xenohyus* and *Teruelia* (giraffid). Problems of age constraint occur because there are no well-calibrated sections in the Iberian basins. Two different dates for the base exist, 22.4 Ma or 22.1 Ma. Further work is needed to place the MN1 - MN2 boundary with more precision.
MN3 can be easiliy recognized. A large number of herbivores entered Europe during this time, including equids (*Anchitherium*), anthracotherids (*Brachyodus*), suids (*Aureliachoerus*), cervids (*Procervulus, Lagomeryx, Acteocemas*), palaeomerycids (*Palaeomeryx*) and proboscideans (Gomphotheridae). Among carnivores this unit is characterized by the genus *Hemicyon*. The age calibration of this unit is made in the North Alpine Foreland Basin, the oldest part of MN3 is correlated to the lower part of chron C6n, and places the base of MN3 at a minimum age of 20 Ma.
MN4 is characterized by the entry of the following large mammals: *Prodeinotherium, Bunolistriodon, Dorcatherium, Eotragus, Megacricetodon* and the disappearance of *Acteocemas* and *Andegameryx*. The MN3 - MN4 boundary has no good age constraint in the Iberian basins, magnetostratigraphic correlations are made in the Schwändigraben-Fontannen section (Swiss), and placed between chrons C5Cn.2r and C5Cr between 16.6 Ma to 17.2 Ma.
A distinction between MN4 and MN5 in Central Europe can be made on the basis of the FAD of the cricetid *Cricetodon*. In Western Europe *Cricetodon* appears in association with *Megacricetodon collongensis*. In Spain *Cricetodon* is missing in most sections with *M. collongensis*. The lower boundary of MN5 is placed now at 16 Ma, at the base of C5Br.
The lower part of MN6 is characterized by the FAD of a second *Megacricetodon* lineage and the replacement of *Bunolistriodon* by *Listriodon*. The upper subunit of MN6 shows the FAD of *Tethytragus, Hispanomeryx* and *Euprox*. The lower boundary of MN6 is placed at 13.7 Ma, at the base of chron C5ABr.

The lower boundary of the MN7 and MN8 unit is placed between chrons C5Ar.1n and C5Ar.3r, between 13 and 12.5 Ma. MN7-like faunas are found in the Valles-Penedes basin characterized by *Cricetodon albanensis, Cricetodon lavocati, Fahlbuschia crusafonti*, the FAD of *Propotamochoerus, Parachleuastochoerus* and *Protragocerus*. The MN8 unit is originally defined by *Hispanomys, Palaeotragus, Protragocerus, Tetralophodon.* The characteristic species *Deperetomys hagni* and *Democricetodon freisingensis* are not recorded in the Spanish basins.

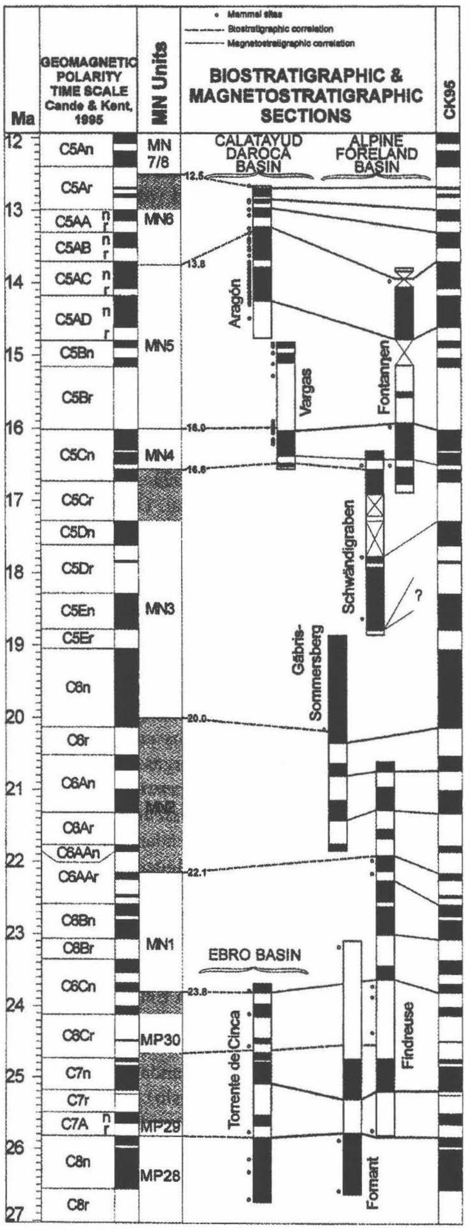

Fig. 1: Biostratigraphic and magnetostratigraphic correlations across the different Lower to Middle Miocene sections of the Calatayud-Daroca, Ebro and Alpine Foreland Basins. Biostratigraphic (magnetostratigraphic) boundary lines correlate towards the time scale on the left (*right*). Shaded time slices in the MN units column represent uncertainities of MN boundary ages. Crosses in the magnetostratigraphic logs represent significant sampling gaps. Correlation of the Fornant-Findreuse and Schwändigraben-Fontannen sections to the GPTS has been reinterpreted (from AGUSTÌ et al. 2001).

The beginning of the Late Neogene is defined by the entry of *Hippotherium.* The base of MN9 is placed at 11.1 Ma (GARCÉS et al. 1997). Small mammal changes include the replacement *of Megacricetodon* and *Fahlbuschia* faunas *by Cricetulodon.*

The lower boundary of MN10 is established in the Valles-Pendes basin at 9.7 Ma in chron C4Ar.3r. In this unit an important faunal change took place at the Early/Late Vallesian boundary, the so-called "Mid-Vallesian Crisis" (MVC), with the disappearance of *Conohyus, Amphiprox, Hispanomeryx, Miotragocerus, Prottragocerus, Lartethotherium sansaniense, Dicerorhinus steinheimensis, Megacricetodon, Eumyarion, Bransatoglis, Myoglis, Paraglirulus, Eomuscardinus, Albanensia, Miopetaurista, Chalicomys* and *Euroxenomys*

(AGUSTÍ & MOYÀ-SOLÀ 1990, AGUSTÍ et al. 1999). In Western Europe this disappearance coincides with the spread of murids.
The lower boundary of MN11 is placed at 8.7 Ma in the upper part of chron C4An. In this unit the extinction of *Rotundomys* and *Anomalomys* occurs. Some artiodactyl taxa disappear and are replaced by *Lucentia* and *Birgerbohlina.*
For the MN11/MN12 boundary two different age calibrations exist, one placing the boundary at 8.0 Ma (base of chron C4n), the second at 7.5 Ma (in chron C4n.1). The unit is characterized by the entry of *Pliocervus, Hispanodorcas, Palaeoryx, Gazella* and *Procapreolus*, while *Dorcatherium, Micromeryx* and *Lucentia* disappear (KRIJGSMAN et al. 1996).

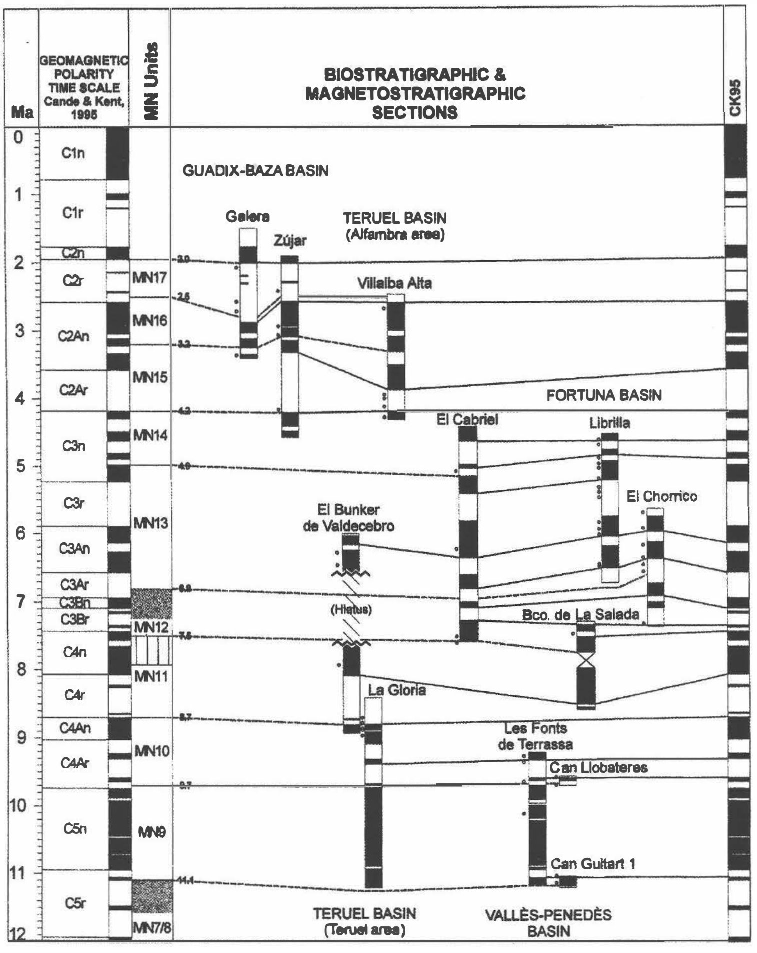

Fig. 2: Biostratigraphic and magnetostratigraphic correlations across the different Upper Miocene and Pliocene sections of the Iberian basins. Stripped rectangle between MN 11 and MN 12 in the MN units log represents the uncertainty of this boundary age due to alternate correlations of the lower part of the Cabriel section (OPDYKE et al. 1997), partly reinterpreted in this paper (from AGUSTÌ et al. 2001).

The MN13 unit records an important turnover: dissapearance of *Parapodemus, Huerzelerimys, Microstonyx, "Procapreolus"*; dispersal and first occurrence of *Macaca* and *Nyctereutes, Hexaprotodon, Paracamelus, Parabos, Paraethomys, Blancomys, Protatera, Calomyscus.*
Recent studies in the Fortuna basin place the boundary between MN12 and MN13 between 6.8-7.2 Ma (between chrons C3Ar and C3Br; KRIJGSMAN et al. 1996, GARCÉS et al. 1998).
MN14 defines the transition from Miocene to Pliocene. The best estimate of the base of MN14 is found in the Cabriel section where a correlation to chron C3n.3r at 4.9 Ma is possible.

References

AGUSTÍ, J. & MOYÀ-SOLÀ, S., 1990: Mammal extinctions in the Vallesian (Upper Miocene). - Lecture Notes in Earth Science, 30, 425-432, Berlin-Heidelberg.

AGUSTÍ, J., CABRERA, L., GARCÉS, M. & LLENAS, M., 1999: The late Miocene terrestrial record in the Vallès-Penedès Basin: Mammal turnover and global climate change. – In: AGUSTÍ, J., ROOK, L., ANDREWS, P., (eds.): The Evolution of Neogene Terrestrial Ecosystems in Europe, Cambridge University Press.

AGUSTÍ, J., CABRERA, L., GARCÉS, M., KRIJGSMAN, W., OMS, O. & PARÉS, J.M., 2001: A calibrated mammal scale for the Neogene of Western Europe. State of the art. - Earth Sci. Rev., 52, 4, 247-260, Amsterdam.

GARCÉS, M., CABRERA, L., AGUSTÍ, J. & PARÉS, J.M., 1997: Old World first appearence datum of "*Hipparion*" horses: late Miocene large mammal dispersal and global events. - Geology, 25, 1, 19-22, Boulder.

GARCÉS, M., KRIJGSMAN, W. & AGUSTÍ, J., 1998: Chronology of the late Turolian of the Fortuna Basin (SE Spain): Implications for the Messinian evolution of the Eastern Betics. - EPSL, 163, 69-81, Amsterdam.

KRIGJSMAN, M., GARCÉS, M., LANGEREIS, C.G., DAAMS, R., DAM, J. VAN, MEULEN, A. VAN DER, AGUSTÍ, J. & CABRERA, L., 1996: A new chronology for the Middle to Late Miocene continental record in Spain. - EPSL, 142, 367-380, Amsterdam.

OPDYKE, N., MEIN, P., LINDSAY, E., PEREZ-GONZÀLES, A., MOISSENET, E. & NORTON., V.L., 1997: Continental deposits, magnetostratigraphy and vertebrate paleontology, late Neogene of Eastern Spain. - Palaeogeography, Palaeoclimatology, Palaeoecology, 133, 129-148, Amsterdam.

Spanish sections: Correlation of magnetozones and MN-zones

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High resolution mammal data from Spain point out the specific problem of MN4, MN5 and MN6 correlations. Especially in the Aragonian area with the Aragonian type section, a good correlation between mammal MN-zones and magnetostratigraphy was constructed. The following table shows the correspondence between the local mammal zones A - I and the MN-zones:

Local zonation	MN zonation
A	3
B	4
C	4
D (Da, Db, Dc, Dd, De)	5
E	5
F	6/7
G	7/8
H	9
I	9

Tab. 1: Correlation of Spanish local mammalia zonation with European MN-zonation.

The Armantes section provided very good magnetostratigraphic results, allowing an unambiguous correlation to the GPTS of CANDE & KENT (1995). The magnetostratigraphy of the Aragonian type section fits quite well to the magnetic record of the Armantes section. The MN4 - MN5 boundary was placed at the top of chron C5 Cn.1n (about 16 Ma), and the MN5

- MN6 boundary at the end of chron C5Acn (Fig. 1). These time constraints raise the problem of a 1 m.y. difference with other correlation schemes, especially in the Central Paratethys and the Eastern Mediterranean area.

The dates of the MN-zones are based on the correlations of our Early Aragonian faunas (local zones B and C) to MN4, of the Middle Aragonian faunas (Zone D) to MN5 and of the Late Aragonian Zones F – G2 faunas to MN6 (DAAMS et al. 1999). MN4 is recognised with the co-occurrence of *Democricetodon* and *Ligerimys* (a characteristic feature of the fauna of La Romieu, reference locality of MN4). MN5 is recognised on the basis of the absence of *Ligerimys* and the expansion of *Hispanotherium* (in agreement with the proposal of the Salzburg meeting in 1995). *Cricetodon* appears in Spain in Zone E. The lower boundary of MN6 is drawn at the replacement of *Megacricetodon collongensis* (last occurrence in Zone E) by *M. gersii* in Zone F. The latter species is present in Sansan, the reference locality of MN6.

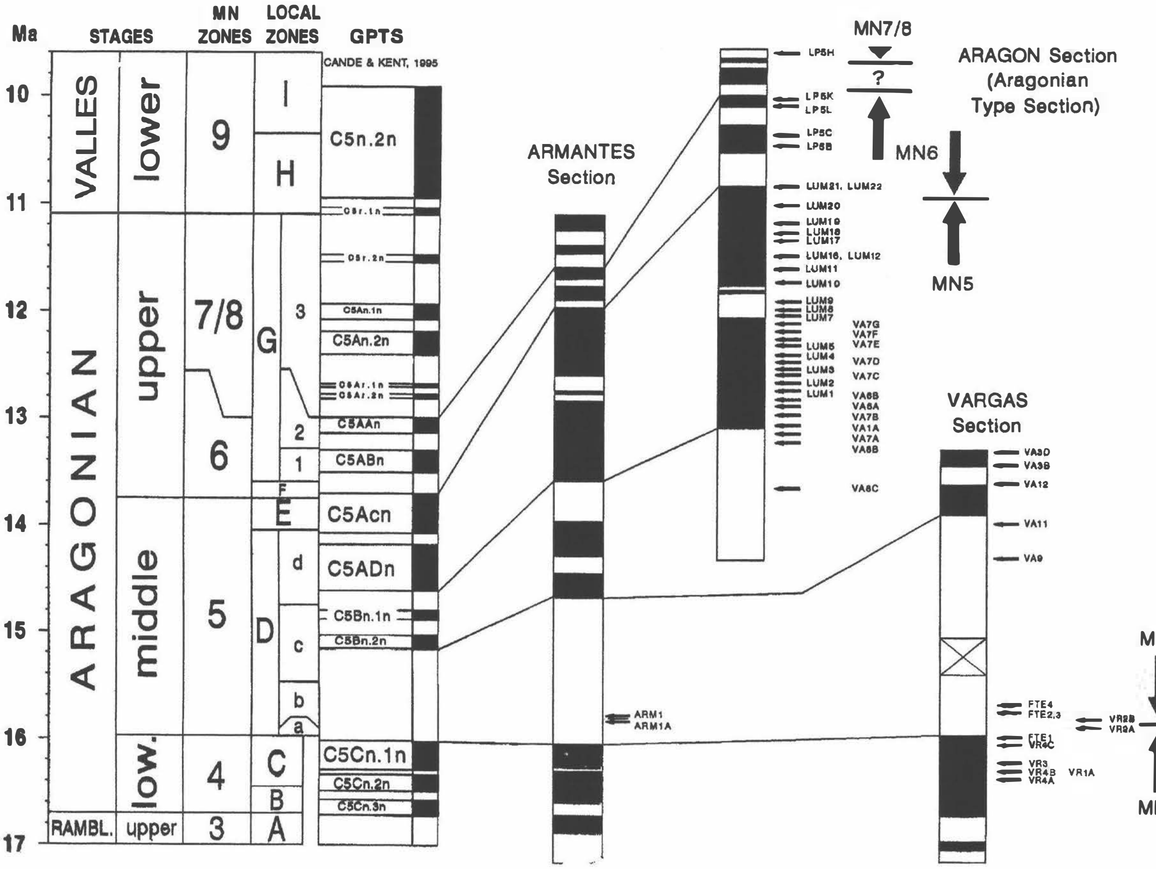

Fig. 1: Magnetostratigraphy, mammal biostratigraphy of Aragonian sections and correlation with GPTS (from DAAMS et al. 1999).

References

CANDE, S.C. & KENT, D.V., 1995: Revised calibration of the geomagnetic polarity timescale for the Late Cretaceous and Cenozoic. – J. Geophys. Res., 100, 4, 6093-6095, Washington, D.C.

DAAMS, R., MEULEN, A.J., ALVAREZ SIERRA, M.A., PELAEZ-CAMPOMANES, P. & KRIJGSMAN, W., 1999: Aragonian stratigraphy reconsidered, and a re-evaluation of the Middle Miocene mammal biochronology in Europe. – EPSL, 165, 3-4, 287-294, Amsterdam.

Early and Late Miocene correlation (Central Paratethys)

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Correlation of marine and continental sequences from different countries is still far from being understood. In addition, there are major differences in correlation of the MN-zones (MN3-6) and the Geomagnetic Polarity Time Scale (GPTS) between SW-Europe and Central Europe (Tab.1 and DAAMS et al. (1999, Fig. 9)).

Therefore, in Austria we primarily concentrate on a few vertebrate faunas, which were deposited in marine or brackish sediments of the Paratethys. Localities which yielded mammal fossils and marine fauna likewise serve as correlation tie points between MN-zones and the marine biozones (based on molluscs, planktonic foraminifera or/and calcareous nannoplankton). For correlation of marine biozones and the Geomagnetic Polarity Time Scale of CANDE & KENT (1995) we follow BERGGREN et al. (1995). This correlation allows us to give a numerical age estimation of marine faunas, and of time equivalent terrestrial faunas, which were brought into the sea and were deposited together with marine animals and nannoplankton in the marine sediments.

Some Austrian vertebrate localities (Figs. 1, 2) focus on correlation in the high-resolution intervals **HRI 3** (13 - 17 Ma) and **HRI 2** (8.5 - 11.5 Ma):

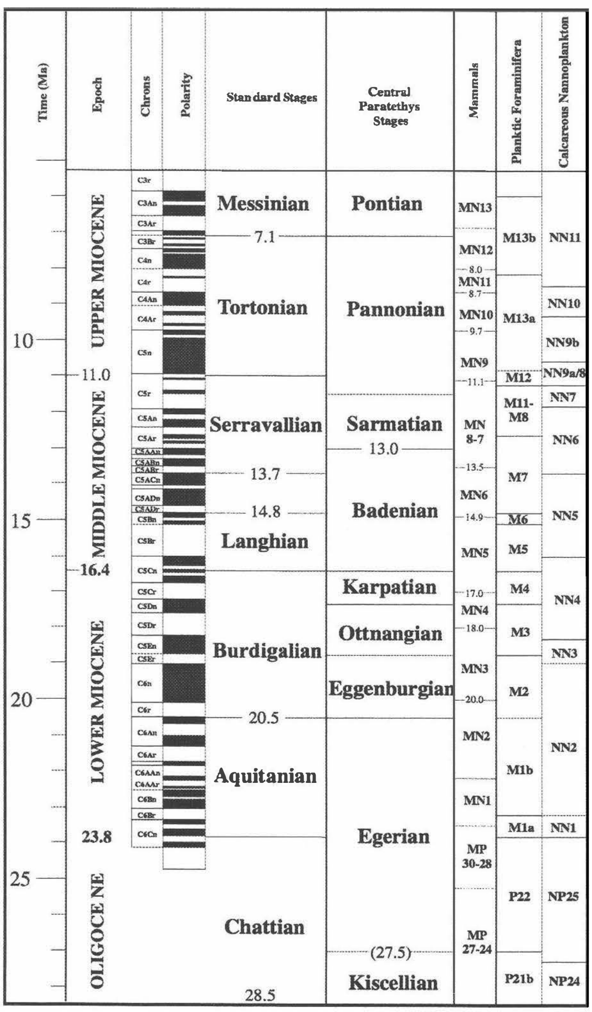

Fig. 1: Correlation chart compiled by HARZHAUSER, RÖGL, DAXNER-HÖCK.

1. The small mammal fauna from **Maigen** (MEIN 1989) in Lower Austria was recovered from marine sediments. It is associated with marine fauna of the lower part of the Upper Eggenburgian. The presence of the small mammals *Ligerimys antiquus, L. lophidens, Melissiodon dominans* and the absence of modern cricetids and glirids confirm the Mammal Zone MN3. Correlation: Upper Eggenburgian and lower-middle part of MN3, respectively.

2. From the hanging wall of the opencast pit of **Oberdorf** in Styria two mammal faunas were recovered (DAXNER-HÖCK et al. 1998). The Mammal Zone MN4 is evidenced by the cricetids *Democricetodon gracilis*, *Eumyarion* aff. *weinfurteri*, *Anomalomys minor* which first occurred in Central Europe in MN4, and by *Ligerimys antiquus*, which was replaced by *Keramidomys thaleri* in MN5. The section shows from bottom to top only one change of magnetic polarity. This change from a reversed (below) to a normal polarity interval (above) occurs approximately 10 meters above the main coal seam. The whole sediment pile above the seam, i.e. the hanging wall (including the two mammal bearing horizons) shows normal polarity (MAURITSCH & SCHOLGER 1998). This normal interval is thought to be Chron C5Dn, because as shown below (3.) the next higher normal interval C5Cn3n corresponds with the lower MN5 and the uppermost part of the Karpatian, respectively. The next lower normal interval C5En corresponds with lower Ottnangian and the higher MN3, respectively. The estimated age of the Oberdorf fauna is 17.3 - 17.6 Ma.

HRI 3: 13-17 Ma

3. The continental vertebrate faunas (terrestrial and aquatic fauna) of **Obergänserndorf** and **Teiritzberg** in Lower Austria were deposited in marine-brackish sediments of the Karpatian sea and therefore were mixed up with marine fauna. Karpatian sedimentation was before the FAD of *Praeorbulina*, which evidences the beginning of the Badenian (Lower Lagenid Zone). The mammal fauna (DAXNER-HÖCK 1998) indicates the lower MN5 by the presence of *Keramidomys thaleri* (being the most abundant fossil), *Democricetodon mutilus, Microdyromys koenigswaldi, Prodryomys satus,* and the absence of *Ligerimys*. Magnetostratigraphic investigations (SCHOLGER 1998) from the very sections with mammal bearing layers (MN5) showed normal magnetic polarity, only. According to BERGGREN et al. (1995) there is only one normal polarity interval Chron C5Cn3n which corresponds with the Karpatian. The following higher Chron C5Cn2n is correlative with the beginning of the Badenian (=Lower Lagenid Zone). The next lower Chron C5Dn corresponds with the Mammal Zone MN4, as demonstrated above (Oberdorf fauna). The estimated age of the vertebrate faunas Teiritzberg and Obergänserndorf is 16.5 - 16.7 Ma.

4. Two mammal faunas from the localities **Grund** and **Mühlbach a. M.** in Lower Austria were recovered from Lower Badenian marine sediments. Although not yet described in detail, we recognized the rodents from Grund and Mühlbach as being more advanced than those from Obergänserndorf and Teiritzberg, i.e. middle-late MN5. Magnetostratigraphic investigations showed normal polarity (SCHOLGER - oral communication), and the marine fauna indicates the Lower Lagenid Zone. The estimated correlation is Chron C5Cn1.

5. The locality **Apfelberg** from the Fohnsdorf Basin in Styria yielded a very small mammal fauna which includes the cricetids *Eumyarion medius, E. bifidus* and *Democricetodon crassus* (STRAUSS, DAXNER-HÖCK & WAGREICH, submitted paper). We correlate the faunula with Sansan in France which is the reference fauna of Mammal Zone MN6.

HRI 2: 8.5 - 11.5 Ma

The HRI 2 corresponds with the Pannonian sedimentation in the Vienna Basin and the Austrian part of the Pannonian Basin. Successive changing of salinity and finally the disappearing of the brackish Pannonian Lake from the eastern part of Austria reflects significant changing of fauna. The Pannonian succession was subdivided by PAPP (1948) into a series of letter-stages, the "zones" A-H, marked by certain mollusc and ostracod taxa .
Some mollusc-ostracod faunas are associated with mammals. They allow correlation of the Pannnian mollusc-"zones" (A-H) and the Mammal Zones MN9-11 (DAXNER-HÖCK 1996). The estimated ages of mammal faunas and the boundaries drawn between MN-zones correspond with Spain. Compare Tab. 1, 2 and VAN DAM (1997, Fig. 2.7).

6. The fauna of **Bullendorf** in Lower Austria yielded molluscs of the lower Pannonian A/B. The associated mammals are very rare and do not include "*Hippotherium primigenium*". Thus, per definition it is no Vallesian, but late Astaracian (MN8) .

7. From the localities **Vösendorf, Inzersdorf** and **Hennersdorf** in Lower Austria rich vertebrate and mollusc faunas indicate the mammal Zone MN9 and the Pannonian "zones" D/E. Magnetostratigraphic investigations in Hennersdorf showed normal polarity. It is the long normal Chron C5n2n.

8. The localities **Götzendorf** and **Stixneusiedl** yielded no murids but mammals indicating late MN9, and molluscs of "zone" F. Normal magnetisation with a low signal of reversed magnetisation at the basal part of the Götzendorf section points to Chron C5n 1n (SCHOLGER - oral communication).

9. The first occurrences of murids in the faunas of **Richardhof** and **Neusiedl a. S**. signalise the beginning of MN10. The freshwater and terrestric gastropods indicate the Pannonian "zone" G/H. Normal polarity of the sediments (SCHOLGER - oral communication) is thought to correspond to Chron C4Ar1n or C4Ar2n.

10. **Kohfidisch** is a fissure filling. The rich small mammal fauna is almost identical with the Turolian Eichkogel-fauna (MN11), but *Progonomys woelferi* was thought to indicate MN10. Discussion is still going on.

11. **Schernham** is a new and so far not described rich vertebrate fauna from the Molasse Basin. It yielded large and small mammals which point to MN10-11.

12. The small mammals from **Eichkogel**, i.e. *Parapodemus lugdunensis, Kowalskia skofleki, Pliopetaurista bressana, Epimeriones austriacus, Collimys primus* and others indicate MN11 (DAXNER HÖCK 1980, 1996), and the according gastropods allow correlation with the mollusc "zone" H. The top of the locality Eichkogel represents the youngest Pannonian small mammal fauna from Austria.

Conclusion: All the biostratigraphic and magnetostratigraphic data from Austrian vertebrate localities (Fig. 2) are brought into line with the correlation chart for GPTS, and marine and continental biozonations (STEININGER 1999, Fig.1.1) which is commonly used in Central Europe (REICHENBACHER et al. 1998 and other authors). But this opinion differs in many respects from the correlation of MN-zones and GPTS data, which is used in Spain. (DAAMS et al. 1999, AGUSTI et al. 2001). There are discrepancies concerning duration and boundaries of MN-zones of the Early and Middle Miocene, but not of the Late Miocene (Tab. 1).

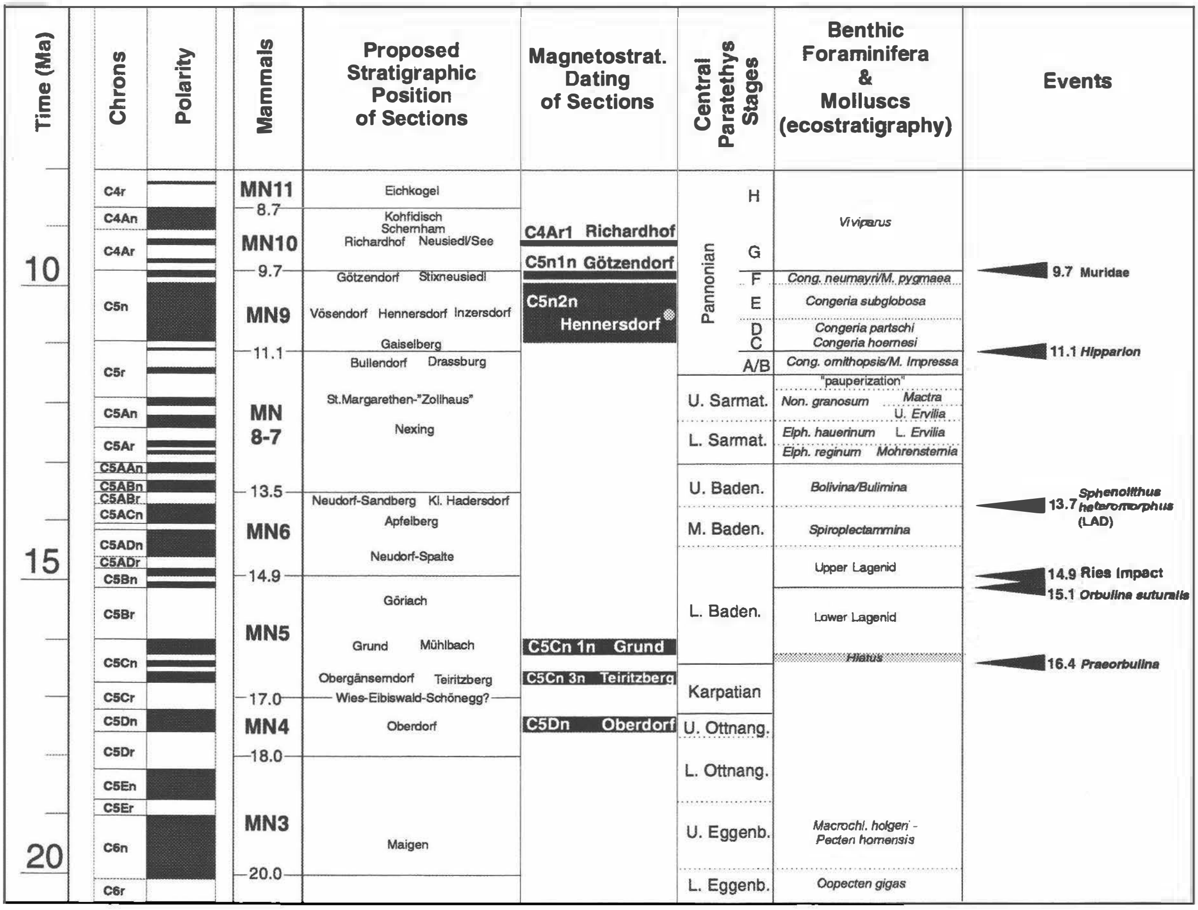

Fig. 2: Correlation of sections and vertebrate localities from Austria (Maigen – Eichkogel) with marine and continental biozonations and the Geomagnetic Polarity Time Scale (GPTS). Compiled by DAXNER-HÖCK, HARZHAUSER and RÖGL.

Lower boundaries of MN-zones:	Numerical ages for MN - boundaries:		
	Steininger 1999	Daams et al. 1999	Agusti et al. 2001
MN4	18.00	17.00	16.60 (17.00)
MN5	17.00	16.00	16.00
MN6	15.00	13.75	13.80
MN7-8	13.50	12.50 (13.00)	12.50 (13.00)
MN9	11.10	11.10	11.10 (11.50)
MN10	9.70		9.70
MN11	8.70		8.70

Tab. 1: Numerical ages for MN-boundaries.

According to different correlation charts the lower boundaries of MN-zones (MN4-8) differ from each other by 1 to 1.25 million years. All these charts are based on very rich data, and the correlation is well proved and confirmed. But, to my opinion the MN-zones are not yet defined clearly. Additional problems arise from endemic faunas which have only a few or no species in common with faunas to compare. Thus, the understanding of MN-zones and their usage is not the same for different authors from distant areas.

My proposal would be to update the MN-zones constantly. It is necessary to give clear information about most abundant and characteristic taxa, the beginning and duration, and the variation of included taxa due to different geographic areas. We should start with certain faunas, which are proved by radiometric, and/or palaeomagnetic, and/or other biostratigraphic data to be of the same age. It is necessary to prove the species determinations of these selected test faunas. If certain taxa are confirmed to be identical they may be used to characterise the very MN-zone.

References

AGUSTÌ, J., CABRERA, L., GARCÉS, M., KRIJGSMAN, W., OMS, O. & PARÉS, J.M., 2001: A calibrated mammal scale for the Neogene of Western Europe. State of the art. - Earth-Sci. Rev., 52, 247-260, Amsterdam.

BERGGREN , W.A., KENT, D.V., SWISHER, C.C. & AUBRY, M.-P., 1995: A revised Cenozoic Geochronology and Chronostratigraphy. - In: BERGGREN, W.A., KENT, D.V. & HARDENBOL, J. (eds.): Geochronology, Time Scales and Global Stratigraphic Correlations: A Unified Temporal Framework for a Historical Geology. - SEPM Special. Publ., 54, 129-212, Tulsa.

CANDE, S.C. & KENT, D.V., 1995: Revised calibration of the geomagnetic polarity time scale for the Late Cretaceous and Cenozoic. - Journal of Geophysical Research, 100, 6093-6095, Washington D.C.

DAAMS, R., MEULEN, A. VAN DER, ALVAREZ SIERRA, M., PELAEZ-CAMPOMANES, P., CALVO, J.P., ALONSO ZARZA, M.A. & KRIJGSMAN, W., 1999: Stratigraphy and sedimentology of the Aragonian (Early to Middle Miocene) in its type area (North-Central Spain). - Newsletter Stratigr., 37, 103-139, Berlin-Stuttgart.

DAXNER-HÖCK, G., 1980: Rodentia (Mammalia) des Eichkogels bei Mödling (Niederösterreich). 1. Spalacinae und Castoridae. 2. Übersicht über die gesamte Nagetierfauna. - Ann. Naturhist. Mus., 83, 135-152, Wien.

DAXNER-HÖCK, G., 1996: Faunenwandel im Obermiozän und Korrelation der MN-"Zonen" mit den Biozonen des Pannons der Zentralen Paratethys. – Beitr. Paläont., 21, 1-9, Wien.

DAXNER-HÖCK, G., 1998: Säugetiere (Mammalia) aus dem Karpat des Korneuburger Beckens. 3. Rodentia und Carnivora. – Beitr. Paläont., 23, 367-407, Wien.

DAXNER-HÖCK, G., HAAS, M., MELLER, B. & STEININGER, F.F., 1998: Wirbeltiere aus dem Unter-Miozän des Lignit-Tagebaues Oberdorf (Weststeirisches Becken, Österreich). 10. Palökologie, Sedimentologie und Stratigraphie. – Ann. Naturhist. Mus., Wien, 99A, 195-224, Wien.

MAURITSCH, H. J. & SCHOLGER, R., 1998: Palaeomagnetism and Magnetostratigraphy from the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). - In: STEININGER, F. F. (ed.): The Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria). – Jb. Geol.B.-A., 140/4, 429-432, Wien.

MEIN, P., 1989: Die Kleinsäugerfauna des Untermiozäns (Eggenburgien) von Maigen, Niederösterreich. – Ann. Naturhist. Mus., Wien, 90, 49-58, Wien.

REICHENBACHER, B., BÖTTCHER, R., BRACHER, H., DOPPLER, G., ENGELHART, W.v., GREGOR, J.-J., HEISSIG, K., HEIZMANN, E. P. J., HOFMANN, F., KÄLIN, D., LEMKE, K., LUTERBACHER, H., MARTIN, E., PFEIL, F., REIF, W., SCHREINER, A. & STEININGER, F. F., 1998: Graupensandrinne - Ries-Impakt: Zur Stratigraphie der Grimmelfinger Schichten, Kirchberger Schichten und Oberen Süßwassermolasse (nördliche Vorlandmolasse, Süddeutschland). – Z. dt. geol. Ges., 149/1, 127-161, Stuttgart.

SCHOLGER, R., 1998: Magnetostratigraphic and palaeomagnetic analysis from the Early Miocene (Karpatian) deposits Teiritzberg and Obergänserndorf (Korneuburg Basin, Lower Austria). – Beitr. Paläont., 23, 25-26, Wien.

STEININGER, F. F., 1999: The Continental European Miocene. Chronostratigraphy, Geochronology and Biostratigraphy of the Miocene "European Land Mammal Mega-

Zones" (ELMMZ) and the Miocene "Mammal-Zones (MN-Zones)". - In: RÖSSNER, G. E. & HEISSIG, K. (eds): Land Mammals of Europe, 9-24, Verlag Dr. Friedrich Pfeil, München.

STRAUSS, P.E., DAXNER-HÖCK, G. & WAGREICH, M., (submitted): Lithostratigraphie, Biostratigraphie und Sedimentologie des Miozäns im Fohnsdorfer Becken (Österreich). – Mitt. Österr. Geol. Ges., Wien.

VAN DAM, J.A., 1997: The Small Mammals from the Upper Miocene of the Teruel-Alfambra Region (Spain): Paleobiology and Paleoclimatic Reconstructions. - Geologica Ultraiectina, Med. Fac. Aardwet.Univ., 156, 1-204, Utrecht.

Correlation of Turkish and Greek mammal localities and magnetostratigraphic data

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The two countries of the Aegean area, Greece and Turkey, have large Neogene basins covering more than 50% of their land surface by continental deposits. About 400 Neogene mammal localities are listed in Turkey, and a hundred in Greece. The Greek Neogene mammalian faunas are reasonably well documented thanks to efforts of old and young paleontologists on more than one and half centuries. This is not the case in Turkey; most of mammal localities are known with preliminary lists, although some reliable efforts have been done since three decades. However, detailed systematic studies on Turkish Neogene mammals exist on some key localities and taxonomic groups (rodents, insectivores, carnivores, proboscideans, etc.), allowing to bring in light some key mammalian events.

The present data show that the correlation of the Aegean mammalian faunal successions with the European Neogene Mammal Chronology (ELMA-ages and MN-zones) remains unsatisfactory. For many intervals of the Neogene, the first and last occurrence datums of taxa are not well documented yet because of insufficient systematic studies and/or radiometric and magnetostratigraphic datings. Moreover, the faunal communities from this area are merely different from that of western Europe, except a few elements in common at genus and species level. This makes the identification of HRI intervals suggested by the EEDEN Committee complicated as well as to use the western European criteria to enlighten the time resolution of mammalian events included in these intervals.

When complete faunas are studied, it is generally observed that the correlation with MN-zones remains a problem, because there are no key elements recognizable. Thus, in the Eastern Mediterranean area it is difficult to use accurately the European zonation; on the other hand there is no other mammal zonation to correlate. Magnetostratigraphic work should help to solve these problems.

Some key localities were pointed out (Fig. 1):
Chios (early Middle Miocene): MN5 faunas from three successive horizons and magnetostratigraphic correlation to C5Br.
Sinap: the lower part of the section is without *Hipparion* which first occurs near the base of C5n at ca. 10.6 Ma.
Igbek: a late Vallesian fauna.

Kavak Dere: the main fossiliferous horizon including Loc. 26 is dated to middle Turolian.
Axios valley (near Thessaloniki): Magnetostratigraphy produced only tentative correlation to the late Vallesian (Xirohori and Ravin de la Pluie) and to the early-middle Turolian (Vathylakkos, Ravin des Zouaves 5 and Prochoma). The sections in this basin are too short for reliable magnetostratigraphic studies.
Comparison of the first apparence datum of some key taxa in Spain and Eastern Mediterranean points to great differences in age:

Hipparion:	Spain: 11.1 Ma	Eastern Mediterranean: 10.6 Ma
Muridae:	10.1 Ma	9.6 Ma

These results raise the question of the diachrony of faunal events and mammalian migrations between Eastern and Western Europe.

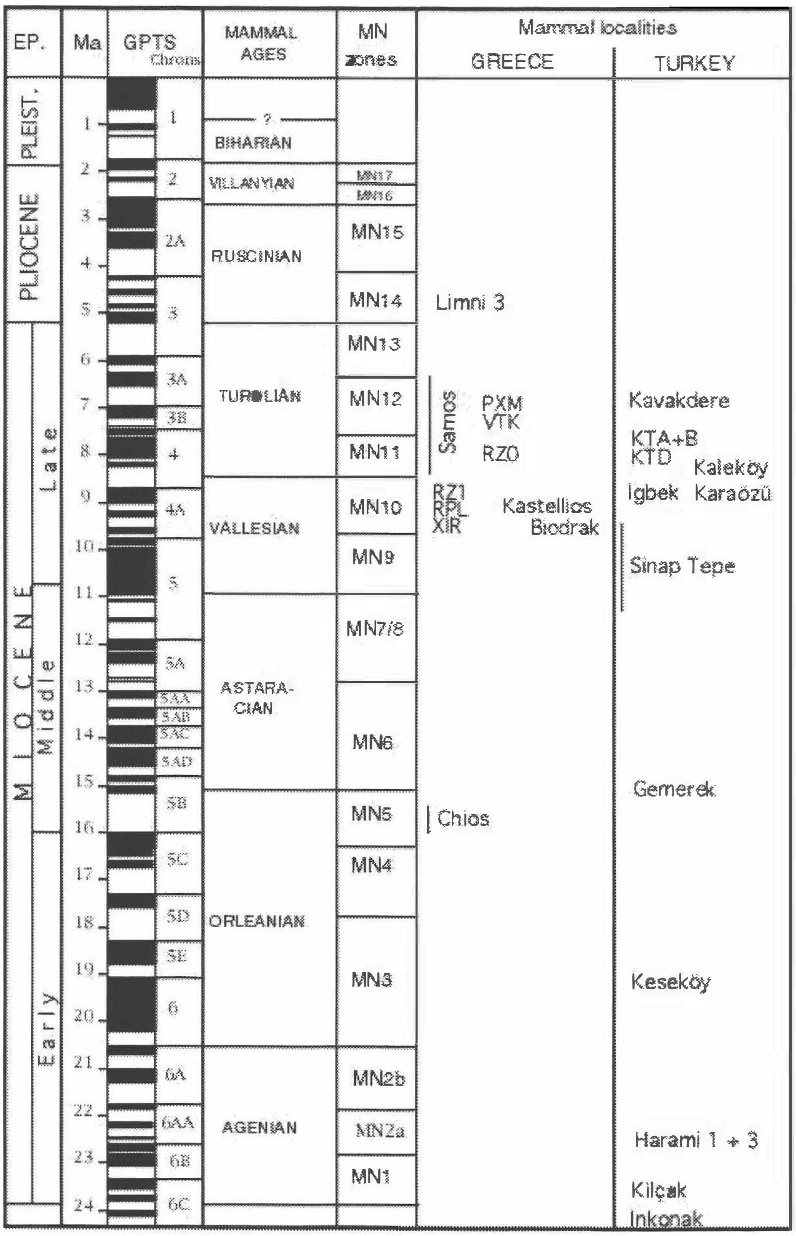

Fig. 1: Some key mammal localities from Greece and Turkey dated by magneto-stratigraphy.

Nature and precision of Neogene mammal chronology – Implications for the EEDEN Programme

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A multivariate method (disjunct distribution ordination, DDO) was applied to a large number of Miocene to Pleistocene localities with mammal faunas from Western Eurasia (Fig. 1). Information was taken at the species level.

Fig. 1: Geographic distribution of localities used in the analyses presented herein. Some localities East of Turkey and the Black Sea are not shown in this figure (from ALROY et al. 1998).

The method creates a sequence of taxonomic first and last appearance events that minimized the total range of each species (Fig. 2).

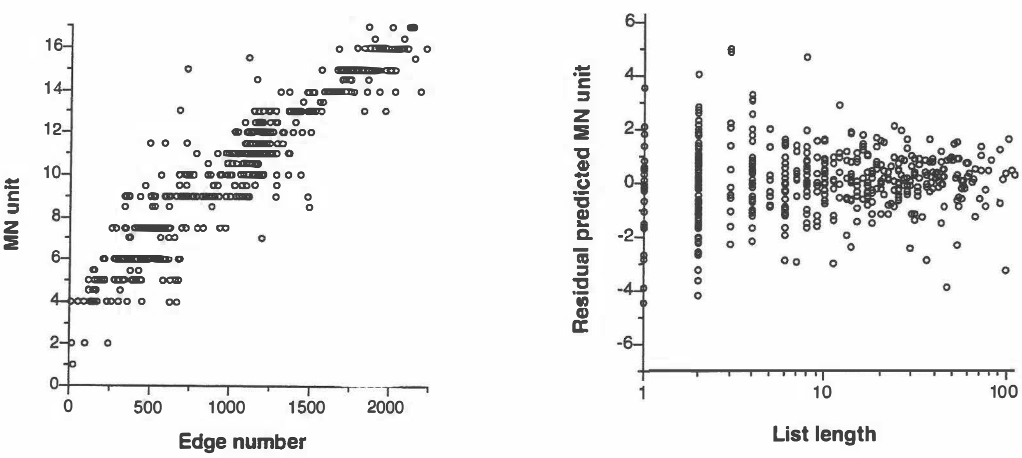

Fig. 2: Diagram on the left showing the correlation between concurrent edge positions and MN unit assignments of faunal lists. Edge numbers are based on a disjunction distribution ordination of the 654 lists in the combined data set. The ordination and the zone assignments reflect the same underlying temporal gradient. Diagram on the right showing the residual predicted MN unit assignments and list lenghts: Longer lists show smaller residuals. Residuals are based on at least-squares fit to the relationship shown on the left side. List lengths are equal to the sum of the number of genera plus species in each list (from ALROY et al. 1998).

Comparison of the DDO sequence with the MN-zonation shows that the two systems give highly similar results in general, although the result may differ by up to four MN units for individual localities. Most of the disagreements between the methods involve faunal lists of inadequate length. The best results are obtained when all localities are included (rather than a geographically defined subset), leading to the conclusion that the MN-zonation can be applied outside the area for which it was created. The results as a whole suggest that the MN-zonation is robust but that it may by itself be less precise than has been commonly assumed.

REFERENCE LOCALITY*	MN UNIT	PREDICTED
St. Vallier	17	17
Triversa	16	16
Arondelli	16	16
Perpignan	15	15
Podlesice	14	14
El Arquillö 1	13	13
Los Mansuetos	12	12
Crevillente-3	11	11
Masia del Barbo	10	10
Can Llobateres	9	8
Anwil	8	7
Steinheim	7	6
Sansan	6	6
Pont Levoy	5	5
La Romieu	4	5
Wintershof-West	3	NO DATA AVAILABLE
Laugnac	2b	NO DATA AVAILABLE
Montaigu-le-Blin	2a	5
Paulhiac	1	NO DATA AVAILABLE

*Note: Reference Localities follow Mein, 1989

Tab. 1: MN unit reference localities: assigned and predicted unit referrals (from ALROY et al. 1998).

For research that does not rely on high resolution stratigraphy the MN-system offers a robust and widely understood basis. For many mammal localities it is currently the best applicable dating method. When available, direct dating and regional biostratigraphic zonations correlated directly with the global time scale offer considerably higher precision, however, and should be a priority for the EEDEN Programme and its databases.

References

ALROY, J., BERNOR, R.L., FORTELIUS, M. & WERDELIN, L., 1998: The MN System; regional or continental? - Mitt. Bayer. Staatsslg. Paläont. hist. Geol., 38, 243-258, München.

MEIN, P., 1989: Updating of MN zones. – In: LINDSAY, E.H., FAHLBUSCH, V. & MEIN, P. (eds.): European Neogene Mammal Chronology, 73-90, Plenum Press, New York.

Paleogeography, paleobiogeography and bathymetry based on fish, particularly otoliths

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Neogene otoliths have to be taxonomically compared with recent species. Otoliths from nearly 6000 Recent species are known (NOLF 1985). For localities with 50-60 species several hundred or thousand kg of sediment is usually needed, therefore samples from drilling cores or boreholes are not reliable for a sufficient interpretation of otolith faunas. All over the world there are only 10 specialists working on otoliths, but the knowledge of the European Neogene basins is quite good. The North Sea Basin belongs to the best investigated basins. In the Aquitanian Basin there is a low level of knowledge in the Serravallian and a very high one in the Langhian and earlier times (Fig. 2).

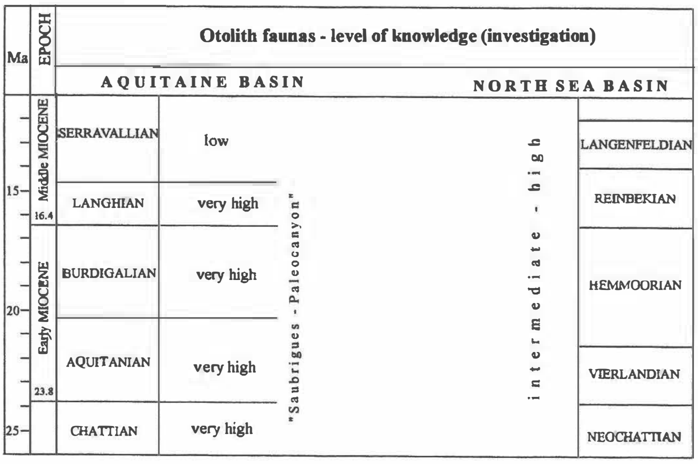

Fig. 1: Level of knowledge of otoliths in North Sea and Aquitanian Basin.

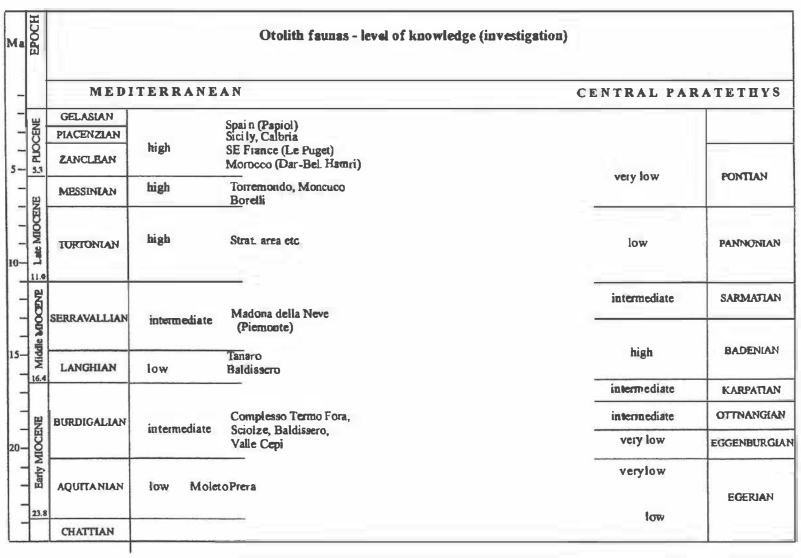

Fig. 2: Level of knowledge of otoliths in the Mediterranean and in the Central Paratethys.

In the Mediterranean there is a low level of knowledge in the Aquitanian and Langhian, intermediate in Burdigalian and Serravallian and high in Tortonian, Messinian and younger stages. In the Central Paratethys there is a low level of knowledge in the Egerian, Eggenburgian, Pannonian, Pontian, intermediate in Sarmatian, Karpatian, Ottnangian and high in Badenian (Fig. 2). Knowledge of otolith faunas is quite unsufficient in the Eastern Paratethys. Otolith associations can be used for bathymetric reconstruction. A generalized approach to the paleobathymetry (neritic – bathyal) can be refined on the basis of the method suggested by NOLF & CAPPETTA (1989) and discussed by NOLF & BRZOBOHATY (1994). This method was used for a paleobathymetric evaluation of the Lower Badenian Carpathian Foredeep (20 localities) in South Moravia (BRZOBOHATY 1997). Four bathymetric associations were proved in the Lower Badenian clay (Fig. 3). Two graphs (Fig. 4) document examples of the deepest association (Brno - Kralovo Pole) and the shallowest one (Kralice n. O.). Results in the map of the Carpathian Foredeep illustrate a proposed paleobathymetry for the Lower Badenian Sea (Fig. 5) and preliminary isobaths (Fig. 6).

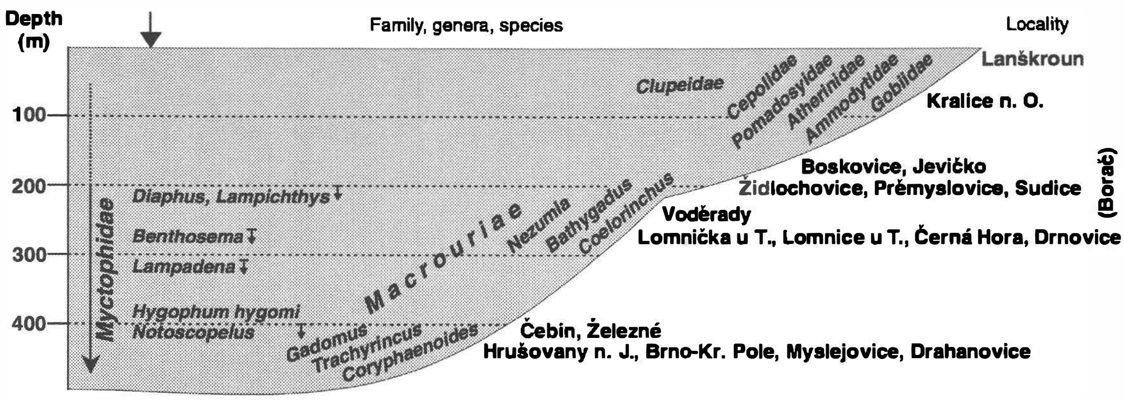

Fig. 3: Actual bathymetric repartition of important teleost taxa represented in the Lower Badenian and their reflexion in localities of the Carpathian Foredeep (South Moravia).

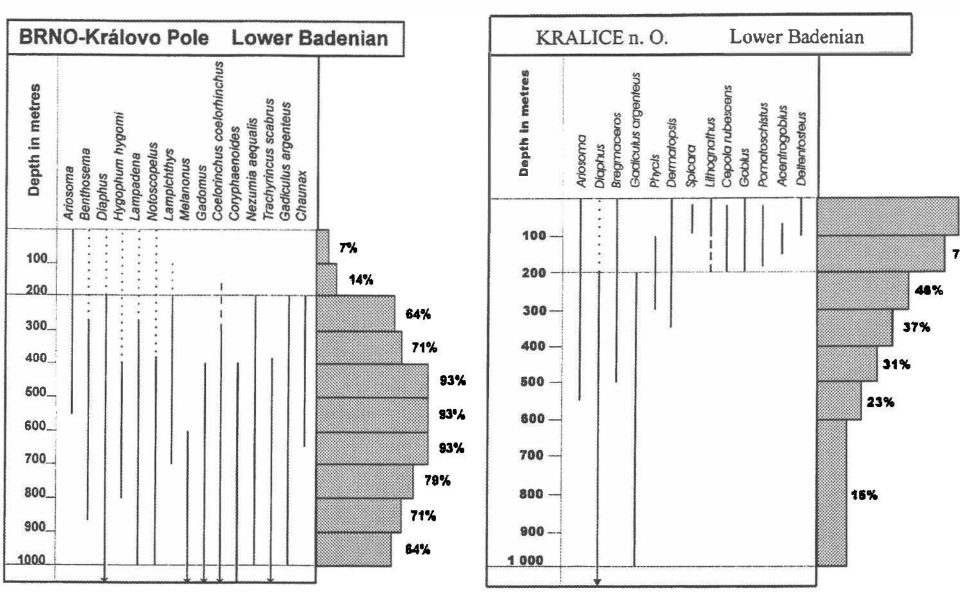

Fig. 4: Actual bathymetric repartition of teleost taxa represented in the Lower Badenian from Brno-Kralovo Pole and Kralice n. O.

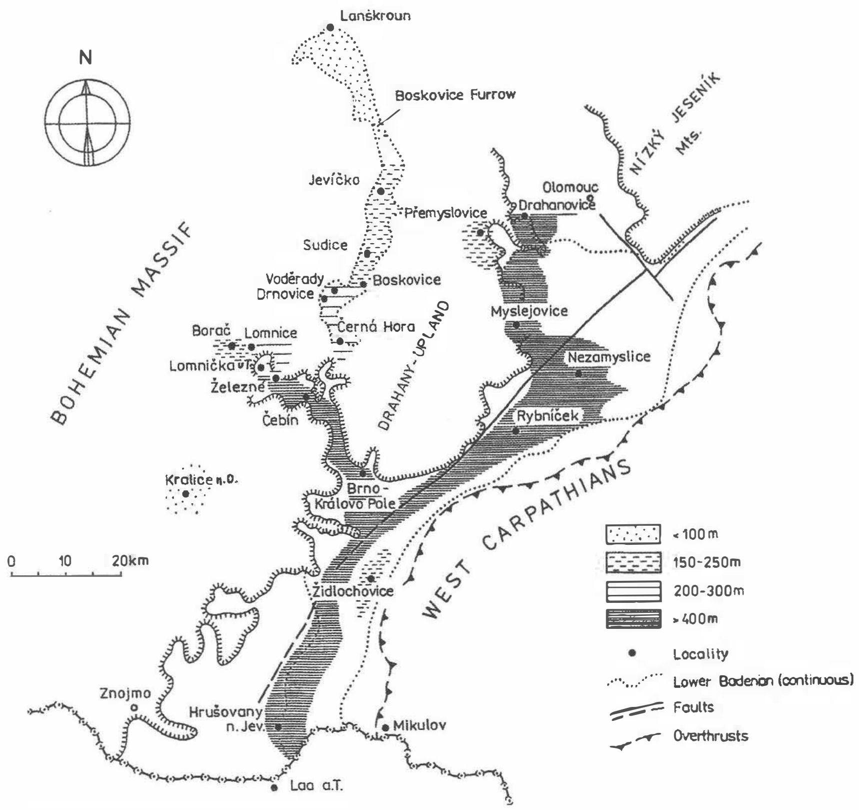

Fig. 5: Position of the Lower Badenian localities in the Carpathian Foredeep (South Moravia) and the paleobathymetric reconstruction.

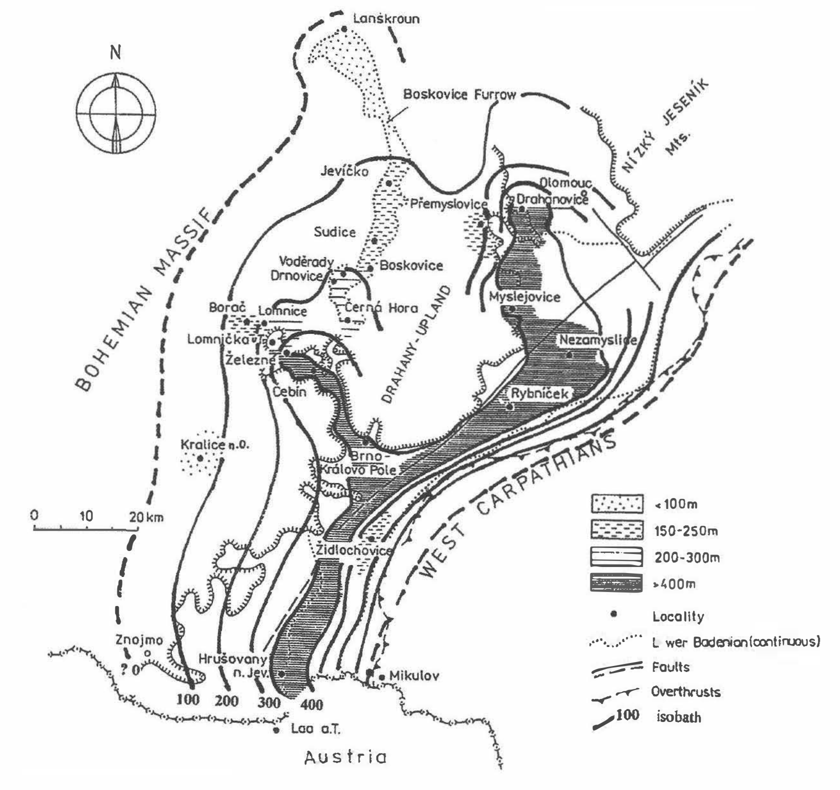

Fig. 6: Preliminary isobath lines in the Lower Badenian Sea of the Carpathian Foredeep (South Moravia).

The Lower Badenian Sea flooded all the relief and archibenthic (Macrouridae) and mesopelagic (e.g., Myctophidae) fauna penetrated through deep depressions to the north and western margin of the basin. Mesopelagic taxa could end up in shallow depths (usually with juvenile specimens, e. g., Kralice n. O.) (Fig. 7).

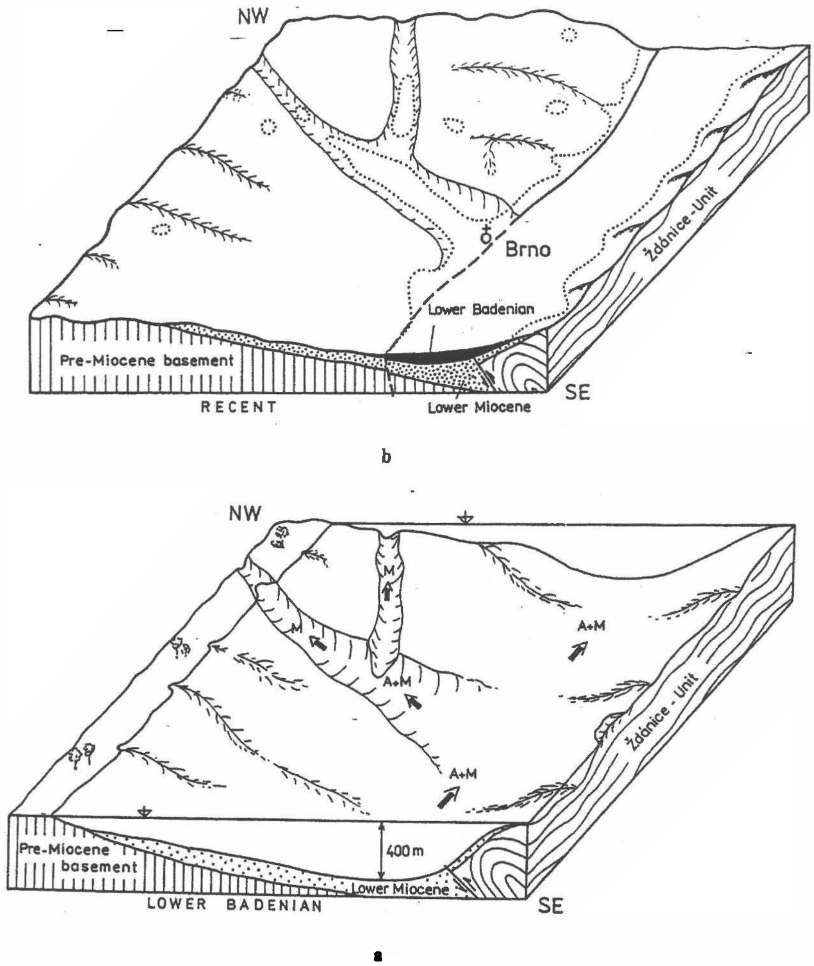

Fig. 7: a = Lower Badenian Sea (A – macrourids, M – mesopelagic fauna), b = recent Carpathian Foredeep with denudation remnants of Lower Badenian deposits.

Comparison of eastern and western parts in the Lower Badenian Central Paratethys shows that in the western parts there are higher numbers of genera and species in Macrouridae and Myctophidae, while in the eastern part Macrouridae are missing and only a low number of genera and species of Myctophidae is present. The Polish Foredeep and the Romanian part of the Central Paratethys seem to be generally shallower than the western part of the Central Paratethys.

References

BRZOBOHATY, R., 1997: Paleobathymetry of the Lower Badenian (Middle Miocene, Carpathian Foredeep, South Moravia) based on otoliths. – In: HLADILOVA, S.: Dynamika vztahu marinniho a kontinentalniho prostredi, Sbornik prispevku, Masarykova universita Brno 1997, 37 – 45, Brno (in Czech, with English resume).

NOLF, D., 1985: Otolithi Piscium. – In: SCHULTZE, H. P.: Handbook of Palaeoichthyology 10. – 145 pp., Fischer Verlag, Stuttgart, New York.

NOLF, D. & BRZOBOHATY, R., 1994: Fish otoliths as paleobathymetric indicators. – Paleontologia i evolucio, 24-25 (1992), 255 – 264, Sabadel.

NOLF, D. & CAPPETTA, H. C., 1989: Otolithes de poissons pliocenens du Sud-Est de la France. – Bull. Inst. Roy. Sci. Nat. Belgique, Sci. Terre, 58, 209 – 277, Bruxelles.

Paleogeography of the Central Paratethys particularly the Vienna Basin

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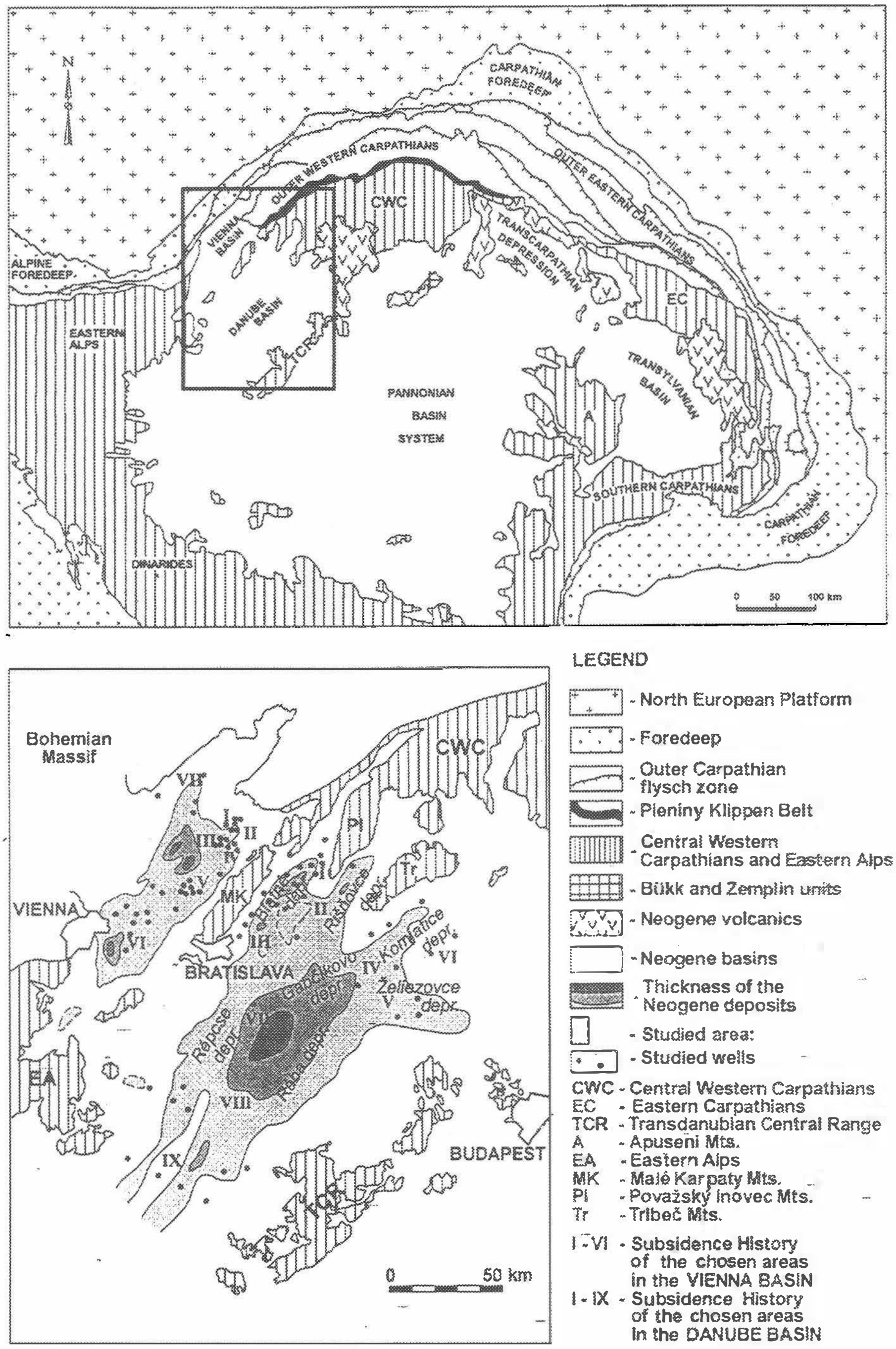

Fig. 1: Map of the studied area (after LANKREIJER et al. 1995).

The approach to reconstruct the basin evolution must be multidisciplinary. Many different results have to be connected: for example, paleogeography, lithostratigraphy, tectonics, relative sea level changes and immigration of new faunas. In detail, the northern (Slovak) part of the Vienna Basin was studied (Fig. 1). The evolution of the "present day" Vienna Basin started with a tectonically controlled subsidence in the Karpatian. In the northern part of the basin a strong tectonic control existed during this time (Fig. 2). During the Middle and Late Miocene the Vienna Basin gained, more or less, a back-arc basin character. All parts of the basin show their individual evolution in time (Fig. 2).

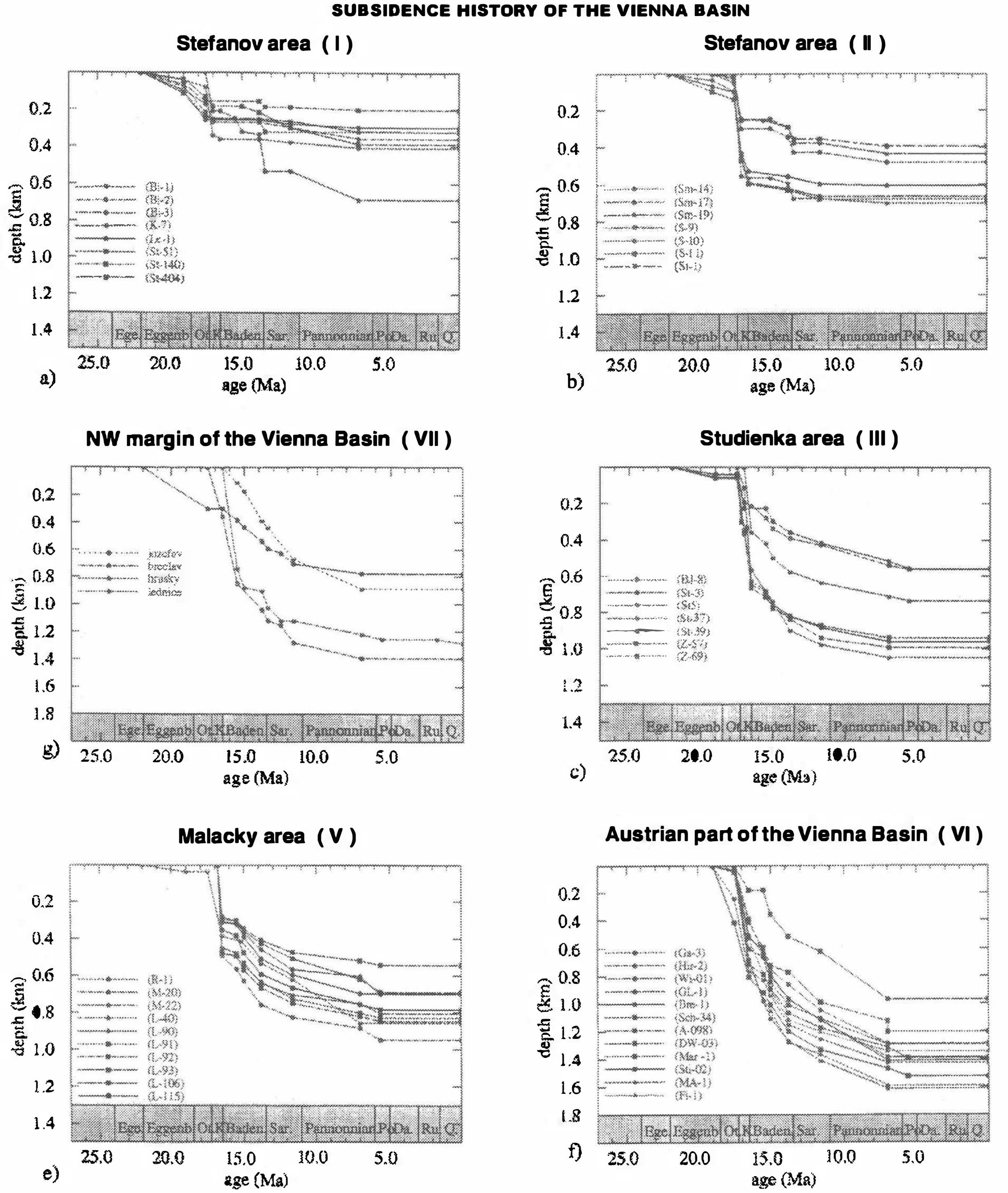

Fig. 2: Comparison of the subsidence history in various parts of the Vienna Basin (LANKREIJER et al. 1995).

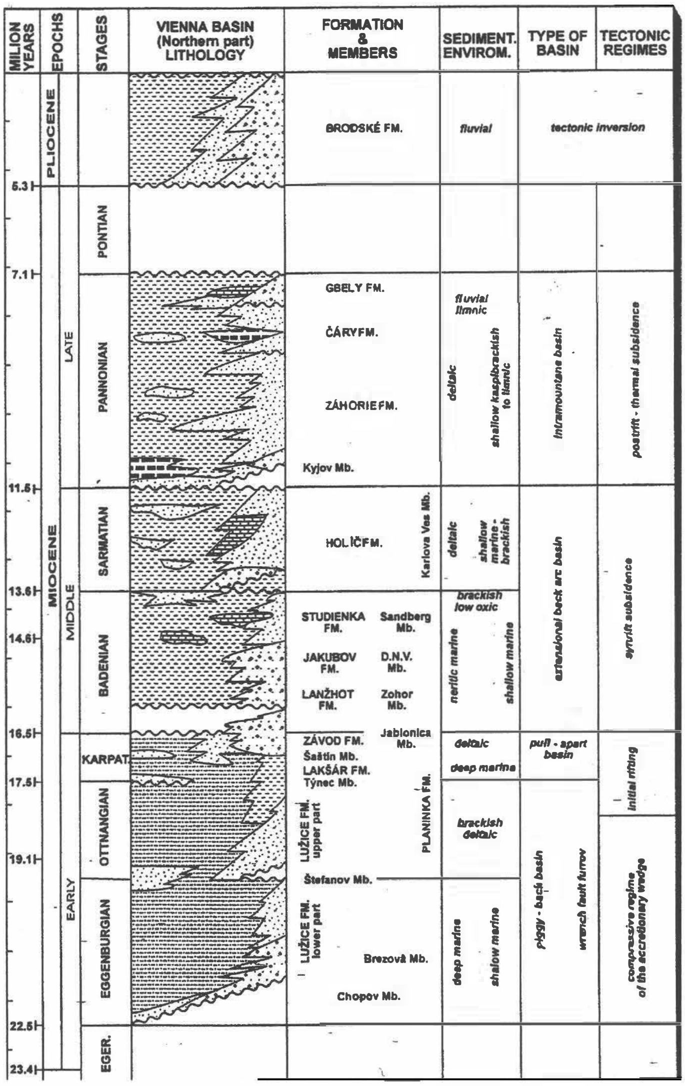

Fig. 3: Miocene lithostratigraphy of the Northern part of the Vienna basin (after KOVÁČ 2000).

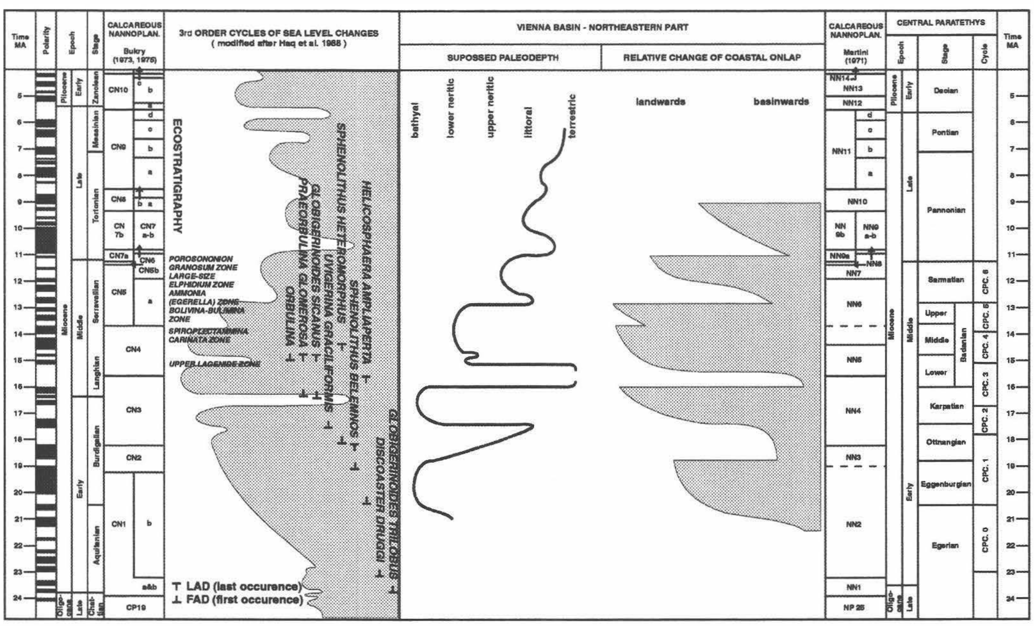

Fig. 4: Coastal onlap and relative sea level changes (paleodepth) in the northeastern part of the Vienna Basin (after HUDÁČKOVÁ 1995, KOVÁČ & HUDÁČKOVÁ 1997, HUDÁČKOVÁ & SLAMKOVA 2000, KOVÁČ et al. 2000).

Localities	MN-zones	Index fossils
Stokerav limestone pit (Neudorf-Spalte)	MN6 (a) (lower part)	*Dinosorex sansaniensis* *Lanthanotherium sansaniensis* *Plesiodimylus chantrei* *Talpa minúta* *Pliopithecus vindobonensis* *Amphicyon major* *Hemicyon sansaniensis* *Cricetodon sansaniensis* *Eomuscardinus sansaniensis* *Microdyromys miocenicus* *Bransatoglis astraracensis* *Chalicotherium grande* *Dicrocerus elegans* *Heteroprox larteti* *Taucanamo sansaniensis* *Zygolophodon turicensis*
Sandberg	MN6 (b) (upper part)	*Griphopithecus suessi* *Pliopithecus antiquus* *Trocharion albanense* *Ursavus brevirhinus* *Dicrocerus elegans* *Heteroprox larteti* *Taucanamo sansaniensis* *Zygolphodon turicensis*
Bonanza	MN6 (b) (upper part)	*Trocharion albanense* *Eumyarion sp.* *Zygolophodon turicensis*
Wait quarry	MN6	*Pristiphoca vetusta*

Tab. 1: Mammal localities and Index fossils (after HOLEC & SABOL 1996, SABOL 2000).

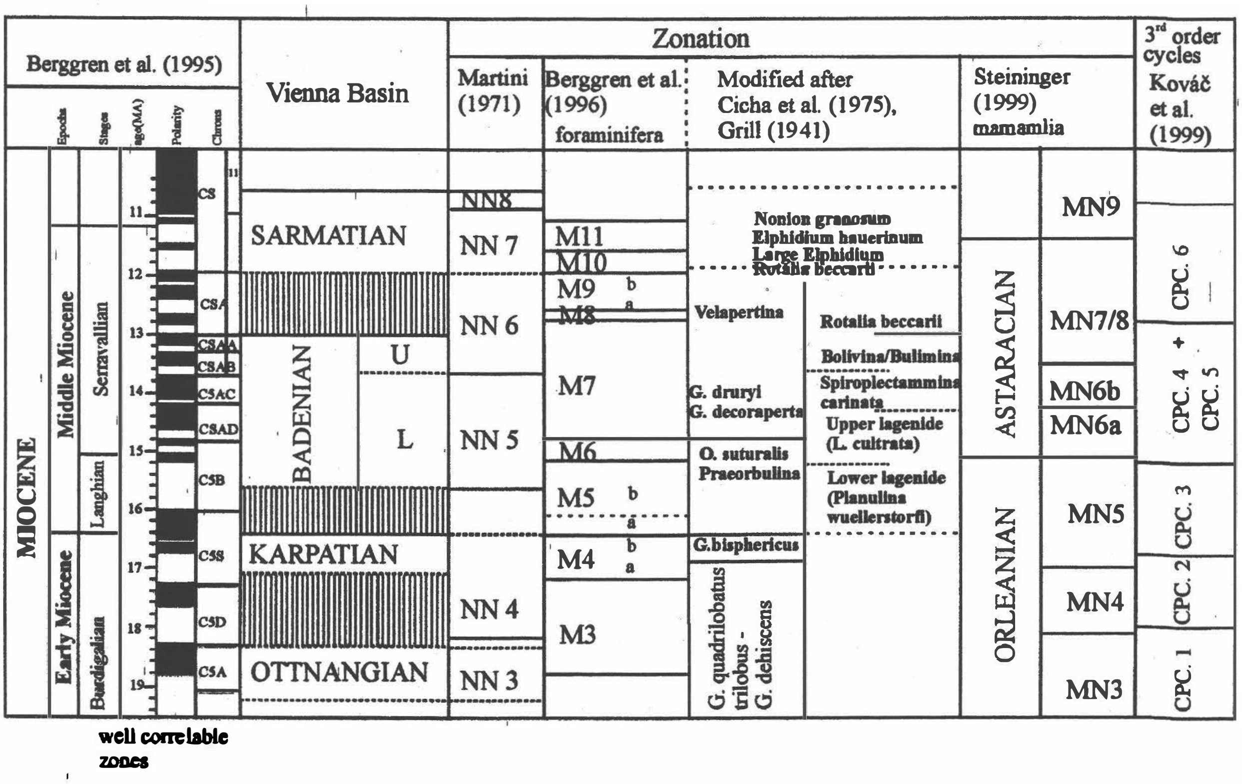

Fig. 5: Compilation of different fossil zonations of the Slovakian part of the Vienna Basin (after HUDÁČKOVÁ et al. 2000).

References

BERGGREN, W.A., KENT, D.V., SWISHER, C.C. & AUBRY, M.-P., 1995: A revised Cenozoic Geochronology and Chronostratigraphy. - In: BERGGREN, W.A., KENT, D.V. & HARDENBOL, J., (eds.): Geochronology, Time Scales and Global Stratigraphic Correlations: A Unified Temporal Framework for a Historical Geology. - SEPM Special. Publ., 54, 129-212, Tulsa.

CICHA, I. & KOVÁČ, M., 1990: Neogene climatic changes and geodynamics of the Central Paratethys. - In: MINAŘÍKOVÁ, D. & LOBITZER, H., (eds.): Thirty years of geological cooperation between Austria and Czechoslovakia, 70-78, Praha.

GRILL, R., 1941: Stratigraphische Untersuchungen mit Hilfe von Mikrofaunen im Wiener Becken und den benachbarten Molasse-Anteilen. - Oel u. Kohle, 37, 595-602, Berlin.

HOLEC, P. & SABOL, M., 1996: Tertiary vertebrates of Devínska Kobyla. - Mineralia Slov., 28, 6, 519-522, Bratislava.

HUDÁČKOVÁ, N., 1995: Ecotype variability of genus Ammonia Brunnich 1772 in Neogene of Paratethys and their paleoecological significance. - Mineralia Slov., 27, 133-144, Bratislava.

HUDÁČKOVÁ, N., 1995: Dinoflagellata from the Pannonian sediments of the NW part of Vienna basin. – Rom. Journ. Stratigr., 76/7,vol 1, Bucharest.

HUDÁČKOVÁ, N., KOVÁČ, M., ANDREYEVA-GRIGOROVIČ, A., BARÁTH, I., HALÁSOVÁ, E., HOLEC, P., SABOL, M., SLAMKOVÁ, M. & HLAVATÝ, I., 2000: The Vienna Basin environment and ecosystem dynamics during the time interval 17-14 MA, results and problems. - EEDEN, Environments and Ecosystem Dynamics of the Eurasian Neogene, 24-26, Lyon.

HUDÁČKOVÁ, N. & SLAMKOVA, M., 2000: Paleoecological reconstruction of the Pannonian sediments of the NW part of the Vienna Basin (slovak part). - Mineralia Slov., 4, 32, 439-441, Bratislava.

KOVÁČ, M., HALÁSOVÁ, E., HOLCOVÁ, K., HUDÁČKOVÁ, N. & ZLINSKÁ, A., 1999: Relationships between eustatic sea-level fluctuations and sedimentary sequences of the Western Carpathian Neogene basins. - Geol. Carpathica, 50, spec. issue, 40-41, Bratislava.

KOVÁČ, M., HUDÁČKOVÁ, N. & BARÁTH, I., 2000: Paleogeography, Geodynamics & Eustacy in the Carpathian – Pannonian region during the Miocene. - EEDEN, Environments and Ecosystem Dynamics of the Eurasian Neogene, 29-38, Lyon.

KOVÁČ, M., 2000: Geodynamic, paleogeographic and structural development of the Carpathian – Pannonian region during the Miocene – New view on the Neogene Basins of Slovakia. - VEDA, 5-203 (in Slovak), Bratislava.

KOVÁČ, M. & HUDÁČKOVÁ, N., 1997 : Changes of paleoenvironment as a result of interaction of tectonic events with sea level changes in the northeastern margin of the Vienna Basin. - Zbl.Geol. Paläont., T.1, H5/6, 457-469, Stuttgart.

LANKREIJER, A., KOVÁČ, M., CLOETINGH, S., PITOŇÁK, P., HLÔŠKA, M. & BIERMANN, C., 1995: Quantitative subsidence analysis and forward modelling of the Vienna and Danube Basins. - Tectonophysics, 252, 433-451, Amsterdam.

MARTINI, E., 1971: Standard Tertiary and Quaternary calcareous nannoplankton zonation. - In: Proceeding of 2nd planktonic conference, 1970, 739-785, Roma

SABOL, M., 2000: Neogene Carnivores of Slovakia. - Slov. Geol. Mag., 6, 2-3, 124-126, Bratislava.

STEININGER, F.F., 1999: Chronostratigraphy, Geochronology and Biochronology of the Miocene “European Land Mammal Mega-Zones” (ELMMZ) and the Miocene “Mammal –Zones (MN-Zones) - In: RÖSSNER, G.E., HEISSIG, K.(eds.) The Miocene Land Mammals of Europe, 9-24, Verlag Dr. Friedrich Pfeil, München.

Miocene and Pliocene palaeogeography of the West European Platform

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Based on stratigraphic and palaeoenvironmental analyses of its numerous Tertiary basins, palaeogeographic maps of the West European Platform have been compiled for the Chattian-Aquitanian, Burdigalian, Langhian-Tortonian, Messinian and Zanclean-Piacenzian time intervals. The sequence stratigraphic records of the basins indicate that Neogene tectonic activity related to intra–plate stresses and plate motions generated by the continuing collision of Apulia and Europe played an important role in basin development, as during the Paleogene. Eustatic changes in sea level induced major changes in the palaeoenvironmental evolution of the West European Platform, for instance by terminating the occurrence of saline passages between basins. In general, minor changes in relative sea level and restricted tectonic events had great impacts on the environmental and depositional development of the generally shallow-water, filled to overfilled basins. These effects are illustrated for the Rhenish Triple Junction, which structure comprises the Upper Rhine Graben, Hessen Depression, Neuwied Basin, and Lower Rhine Embayment. In particular, the episodic existence of saline communication of the Upper Rhine Graben with the external marine realms is evidenced by the immigration of different species of fish from the north (North Sea Basin), the south (Mediterranean Basin) or the east (Paratethys).

Stratigraphy and paleogeography of the Eastern Paratethys

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<u>Stratigraphy</u>

"Gold nails" for Paratethyan stratigraphy are several brackish levels in the basin evolution and their related occurrence of endemic biota. An explosive evolution of ancestral marine euryhaline forms and rapid extinction in unstable environments of semi-closed basins are observed among molluscs, ostracods, diatoms, and dinocysts. They provide a possibility for precise stratigraphic correlations. The best studied and most useful group are the molluscs.

The first appearance of specific Paratethyan short-lived endemics took place as a result of the Solenovian brackish event during the Rupelian (BALDI 1984, VORONINA & POPOV 1984, MERKLIN 1974, RUSU 1988, NAGYMAROSY & VORONINA 1993). This event distinctly influenced the mollusc, ostracod (*Disopontocypris oligocaenica* - Association), calcareous nannoplankton (bloom of *Reticulofenestra ornata*, *Transversopontis fibula*), and dinocyst composition as well as the sediments. It is recognized from the Alps to Lake Aral and Kopet-Dagh and reflected in the stratigraphic scheme of Fig. 1 as Level 1. The Solenovian mollusc fauna possibly originated in the Transcaucasian area (South Georgia, Akhaltsikhe).

The second event occurs in the Upper Ottnangian – Kozakhurian (Level 2 in Fig. 1). This brackish level is based on molluscan and foraminiferan data and can be observed from the Swiss Molasse Basin to the northern Lake Aral area and the western Kopet-Dagh (POPOV & VORONINA 1983). Transitional forms from euryhaline ancestral *Cerastoderma* to endemic *Limnopagetia* and *Limnopappia* are observed in material from Bavaria (SCHLICKUM 1962, 1963, 1971). Later, this molluscan fauna inhabited the Eastern Paratethys (known from Georgia and Kopet-Dagh) without the transitional forms.

The third level (Fig. 1), important for interregional correlation, is observed at the base of the Sarmatian and is marked by a pronounced impoverishment of marina biota and the appearance of more than 20 endemic species (3 species of *Inaequicostata*, *Mactra eichwaldi*, and *Obsoletiforma lithopodolica* were widespread in the Eastern and Central Paratethys). A second wave of appearance and spreading of endemic species occurred in the Middle Sarmatian s. l. (Bessarabian) among molluscs (*Mactra vitaliana*, *Obsoletiforma praefischeriana*, *Venerupis ponderosa*), ostracods, and foraminifera (Level 4 in Fig. 1).

The last level of short-lived, widespread endemics is observed in the basal Pontian - Late Messinian, which is marked by several molluscan genera (*Limnocardium*, *Pseudocatillus*, *Eupatorina*), the ostracod *Loxoconcha djaffarovi* – Association, and endemic dinocyst species (Level 5 in Fig. 1). An ancestral association of Pontian molluscs occurs in the Late Messinian (POPOV & NEVESSKAYA, 2000). A second wave of widespread Paratethyan endemics can be observed at the base of the Upper Pontian (Portaferian). All paleomagnetic data from the Eastern Paratethyan Pontian, basal layers excluded, are characterized by reverse polarity which is correlated with Chron C3r (TRUBICHIN, 1989). Consequently, the Upper Maeotian, which is dominated by normal polarity, has to be correlated with Chron C3An, and the Lower Maeotian, predominantly of reverse polarity, with C3Ar - C3Br. Generally, the Maeotian corresponds with the Lower Messinian (TRUBICHIN 1989, MOLOSTOVSKII & KHRAMOV 1997). The Middle Sarmatian s. l. corresponds to Chron C5n in the upper part based on a long-term normal polarity interval (TRUBICHIN 1989), nannofossils of Zones NN8-NN9 (MARUNTEANU 1993), and mammals of Zone MN10.

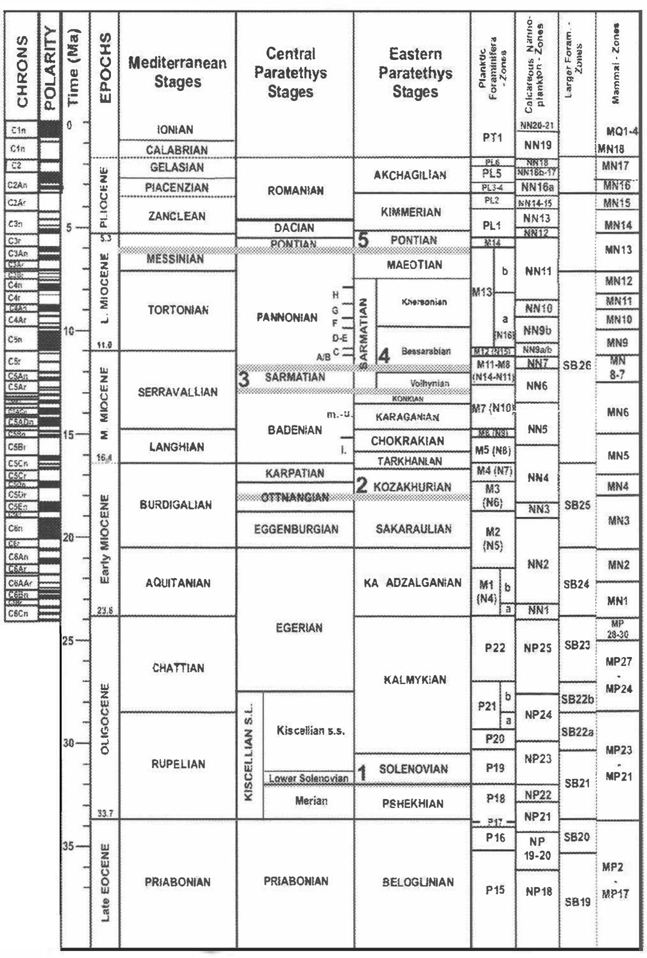


Fig. 1: Stratigraphic scheme of parts of the Cenozoic Mediterranien and Paratethys and main levels of appearance of brackishwater endemics:
Level 1 (Solenovian): first appearance of *Ergenia, Urbnisia, Korobkoviella, Merklinicardium*; Level 2 (Upper Ottnangian-Kozakhurian): appearance of *Rzehakia dubiosa, Limnopagetia, Eoprosodacna*; Level 3 (Lower Sarmatian): widespread of *Obsoletiforma, Plicatiforma, Inaequicostata, Abra reflexa, Mactra eichwaldi*; Level 4 (Middle Sarmatian s.l.): wide spreading of *Mactra vitaliana, M. podolica, Venerupis ponderosa, Obsoleti-forma praefisheriana, Inaequicostata barboti*; Level 5 (Pontian-Upper Messinian): first appearance of *Lymnocardium, Pseudocatillus, Eupatorina*).

Paleogeography

Within the framework of the Peri-Tethys Programme, a set of 10 paleogeographic maps of the Paratethys (scale 1:7,500.000) were worked out for the following time slices:
1) Late Eocene (Priabonian), 2) Early Rupelian (before Solenovian), 3) Chattian (Egerian – Kalmykian), 4) Early Burdigalian (Eggenburgian – Sakaraulian), 5) Langhian (Early Badenian – Chokrakian), 6) Middle Serravallian (Late Badenian – Konkian), 7) Late Serravallian (Sarmatian), 8) Late Tortonian – Early Messinian (Early Maeotian), 9) Late Messinian (Pontian), and 10) Piacenzian – Gelasian (Akchagilian).

Palinspastic maps (1:20,000.000) were reconstructed after finishing the Peri-Tethys Programme. For the older time intervals they are presented in Maps 1–4. Five maps for the 3 high-resolution intervals (HRI 1 – 3) are currently worked out. Within the EEDEN Programme they can act as a base for terrestrial and marine biogeography as well as for water and wind circulation models.

References

BALDI, T., 1984: The terminal Eocene and Early Oligocene events in Hungary and the separation of an anoxic, cold Paratethys. - Eclogae Geol. Helv., 77, 1, 1-27, Basel.

JAZU & SANU, 1989: Pontien. Chronostratigraphia and Neostratotypes. Bd. 8. – 952 pp., Zagreb, Beograd.

MARUNTEANU, M., PAPAIANOPOL, J., POPESCU, GH., OLTEANU, R., MACALET, R., PETREA, S. & PETCU, J., 1998: Biostratigraphic studies for the standard scale of the Neogene - Moesian and Moldavian platforms. - Rom. Journ. Stratigr., 78, Bucharest.

MERKLIN, R.L., 1974: Handbook of bivalve molluscs of the Oligocene in the southern part of the USSR, Moscow: Nauka, 172 p. (Russ.).

MOLOSTOVSKII, E.A. & KHRAMOV, A.N., 1997: Magnetostratigraphy and their meaning in geology. - 180 pp., Saratov: Saratov Univ. Publ. House.

NAGYMAROSY, A. & VORONINA, A., 1993: Calcareous nannoplankton from the Lower Maykopian Beds (Early Oligocene, Union of Independent States). - Nannoplan. Research, 2, 189-223.

POPOV, S.V. & NEVESSKAYA, L.A., 2000: Late Miocene brackish-water mollusks and the history of the Aegean Basin. - Stratigraphy, Geol. Correl., 8/2,195-205.

POPOV, S.V. & VORONINA, A.A., 1983: Kozahurian stage of the Eastern Paratethys. - Izvestia AS USSR. Ser. Geol., 1, 58-67 (Russ.).

RUSU, A., 1988: Oligocene events in Transilvania (Romania) and the first separation of Paratethys. - D.S. Inst. Geol. Geofiz., 72-73, 207 - 223.

SCHLICKUM, W.R., 1962: Die Gattung *Limnopappia* n. gen. - Arch. Moll. 1962, 91, N.1/3,102-115.

SCHLICKUM, W.R., 1963: Die Molluskenfauna der Süssbrackwassermolasse von Ober- und Unterkirchberg. - Arch. Moll., 92, N1/2, 1-10.

SCHLICKUM, W.R., 1971: Die beiden miozänen Brackwasserbecken der süddeutschen Molasse und ihre Molluskenfauna. - Senckenberg. Lethaia, 52, 5-6, 569-581.

TRUBICHIN, V.M., 1989: Paleomagnetic scale and Neogene - Quarternary stratigraphy of the Paratethys. - In: "Key sections of the Eastern Paratethys", Abstr. volume. Volgograd, Taman., 13-17 (Russ.).

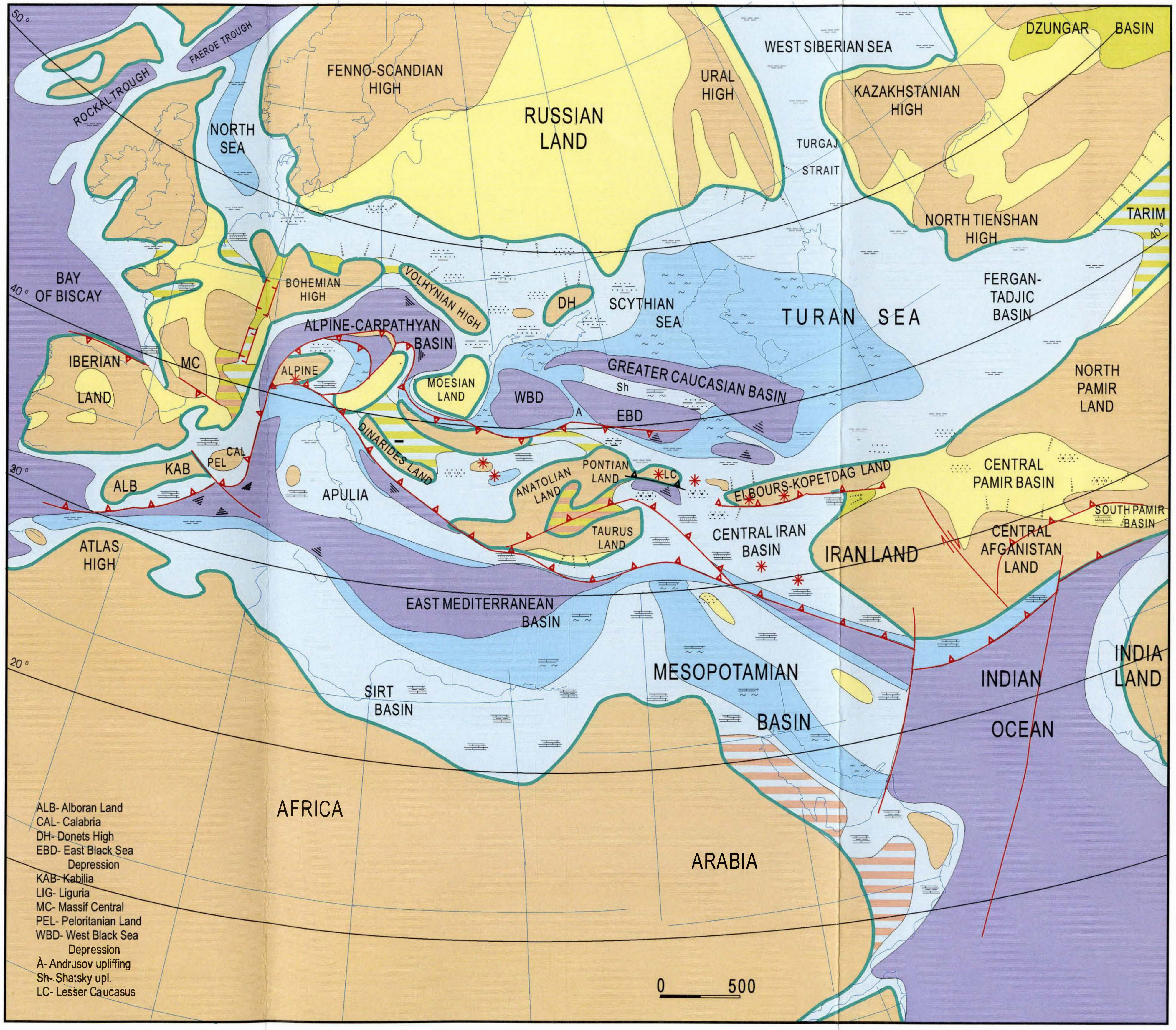
VORONINA, A.A. & POPOV, S.V., 1984: Solenovian Horizon of the Eastern Paratethys. - Izvestia AS USSR. Ser. Geol., 9, 41-53 (Russ.).

Map 1

Lithological-Paleogeographic maps of Paratethys: Late Eocene

Compiled by S.V. Popov, I.G. Shcherba, A.S. Stolyarov

Co-authors:
B.I.Pinkhasov (Turan area),
A.Nagymarosy (Hungarian Basin),
A.Rusu (Transylvania, S.Carpathians),
F.Roegl (Hellenids, Pre-Alpine Basin),
V.A.Krasheninnikov (North Arabia),
K.Guers (NW Europe)

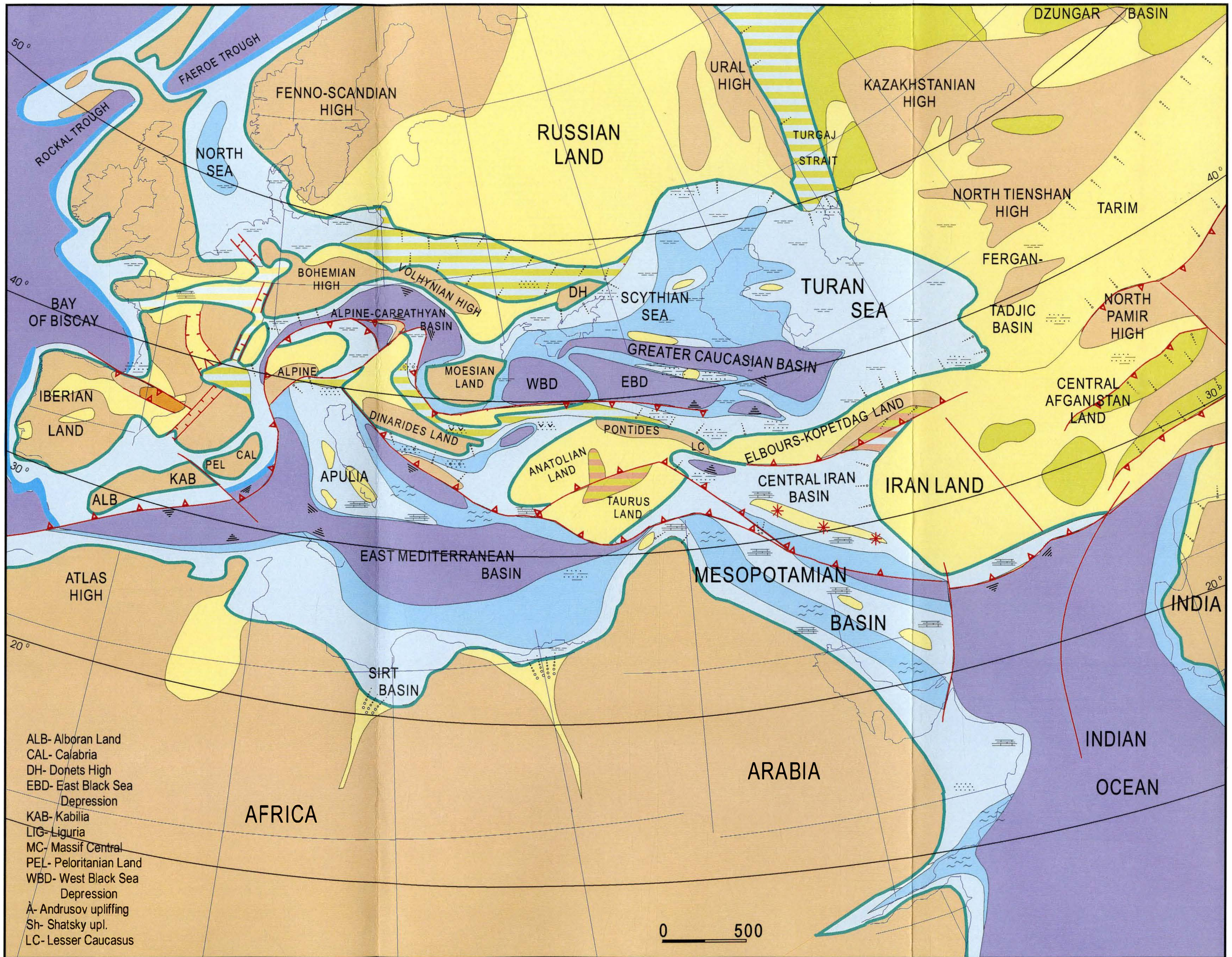


Map 2

Lithological-Paleogeographic maps of Paratethys: Early Oligocene

Compiled by S.V. Popov, I.G. Shcherba, A.S. Stolyarov

Co-authors:
B.I.Pinkhasov (Turan area),
A.Nagymarosy (Hungarian Basin),
A.Rusu (Transylvania, S.Carpathians),
F.Roegl (Hellenids, Pre-Alpine Basin),
V.A.Krasheninnikov (North Arabia),
K.Guers (NW Europe)

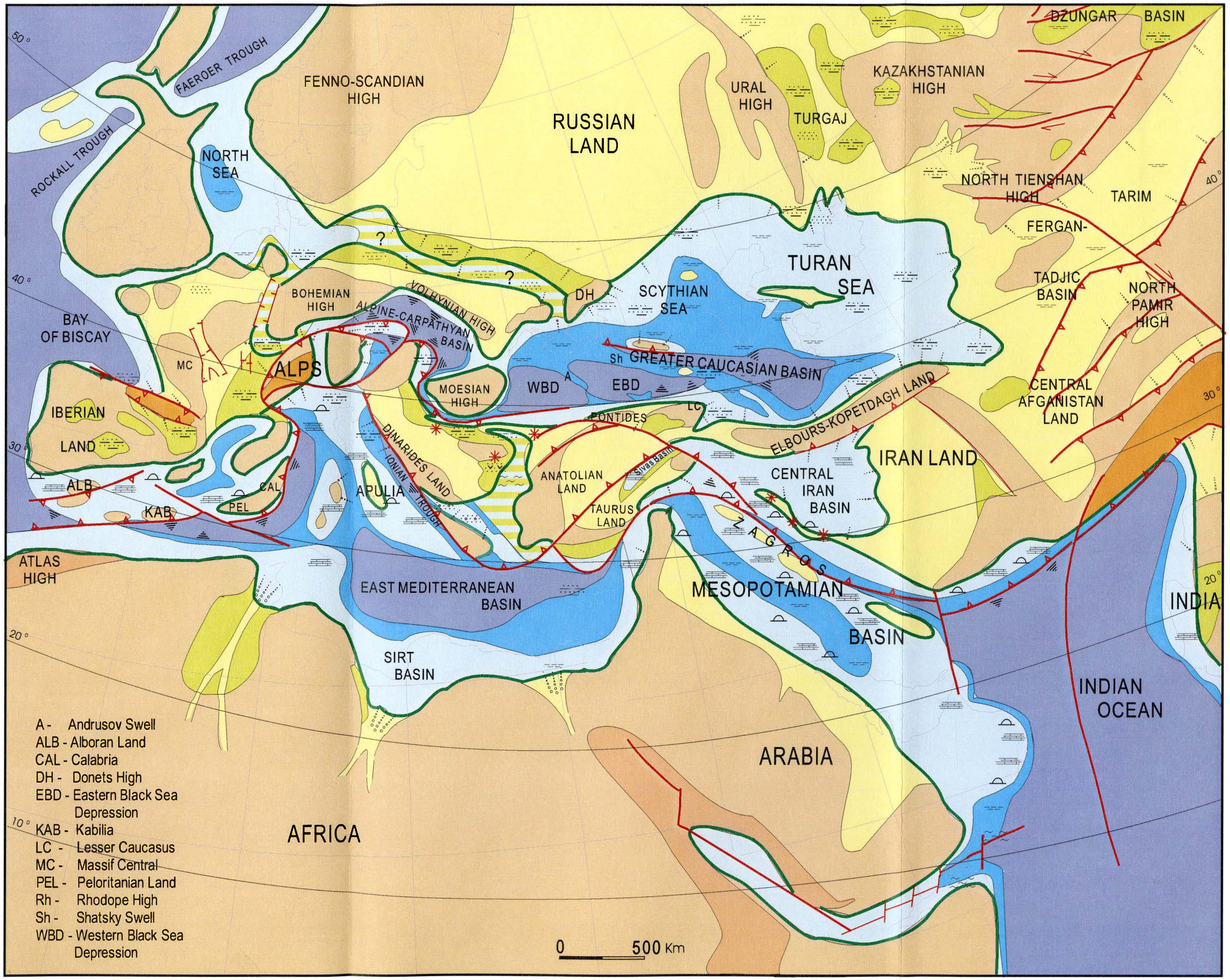


Map 3

Lithological-Paleogeographic maps of Paratethys: Late Oligocene

Compiled by S.V. Popov, I.G. Shcherba, A.S. Stolyarov

Co-authors:
B.I.Pinkhasov (Turan area),
A.Nagymarosy (Hungarian Basin),
A.Rusu (Transylvania, S.Carpathians),
F.Roegl (Hellenids, Pre-Alpine Basin),
V.A.Krasheninnikov (North Arabia),
K.Guers (NW Europe)



Map 4

Lithological-Paleogeographic maps of Paratethys: Early Miocene

Compiled by S.V. Popov, I.G. Shcherba, A.S. Stolyarov

Co-authors:
B.I.Pinkhasov (Turan area),
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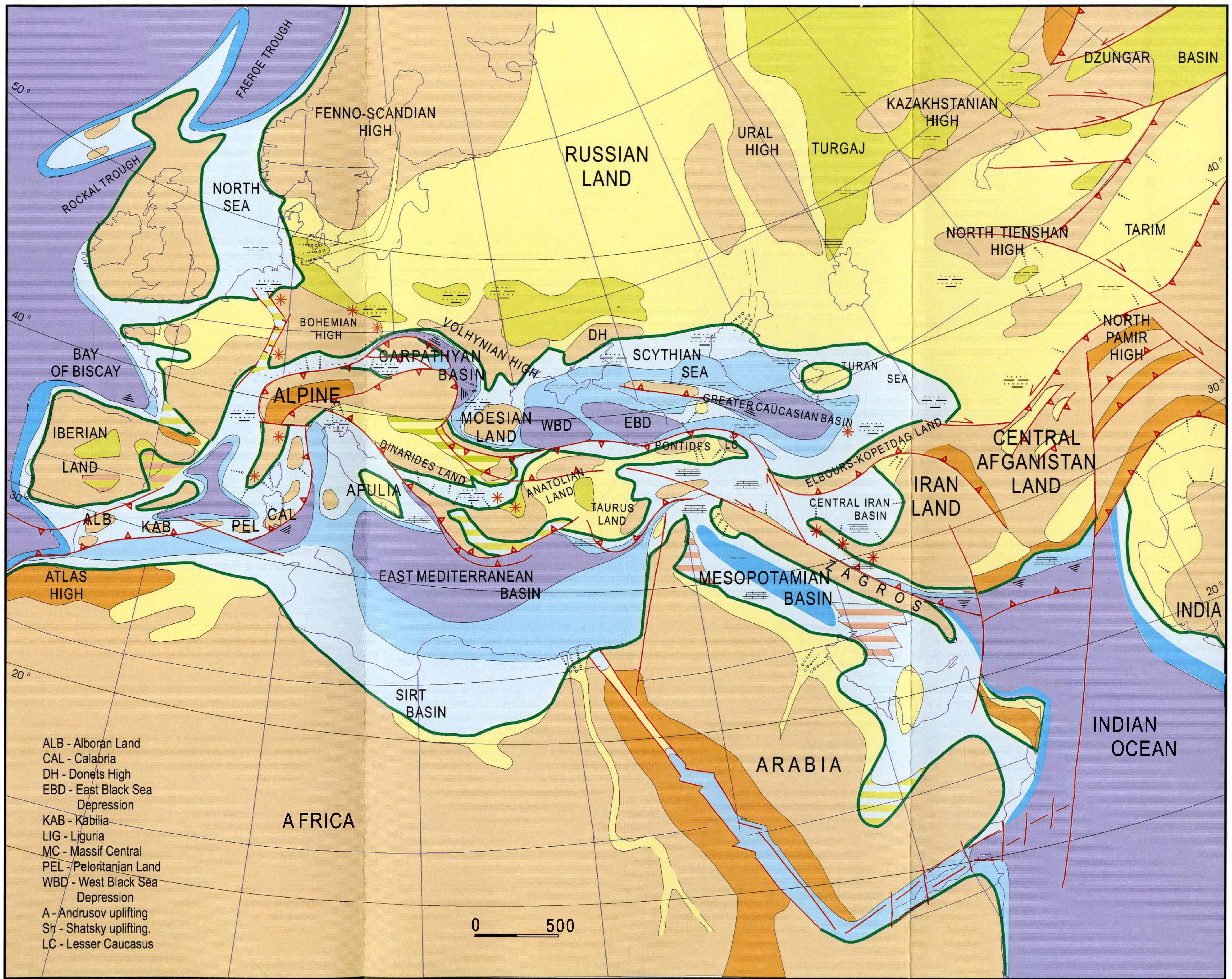
A.Rusu (Transylvania, S.Carpathians),
F.Roegl (Hellenids, Pre-Alpine Basin),
V.A.Krasheninnikov (North Arabia),
K.Guers (NW Europe)



Mid-Miocene Circum-Mediterranean paleogeography

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A brief overview of the Circum-Mediterranean paleogeography (RÖGL 1998, 1999) is given to stimulate the discussion on open problems. There are excellent reconstructions on the paleogeography and sediment distribution of the Oligocene - Early Miocene of the Eastern Paratethys (POPOV et al. 1993). A Middle Miocene (Badenian) paleogeographic reconstruction of the Paratethys was presented by STUDENCKA et al. (1998), but is based on a different stratigraphic correlation. Fig. 1 shows the present correlation of the Central and Eastern Paratethys as proposed by the author. The correlation with the absolute time-scale follows BERGGREN et al. (1995); the differences of the Langhian-Serravallian boundary depend on different interpretations, and a missing boundary-stratotype (FORNACIARI et al. 1997).

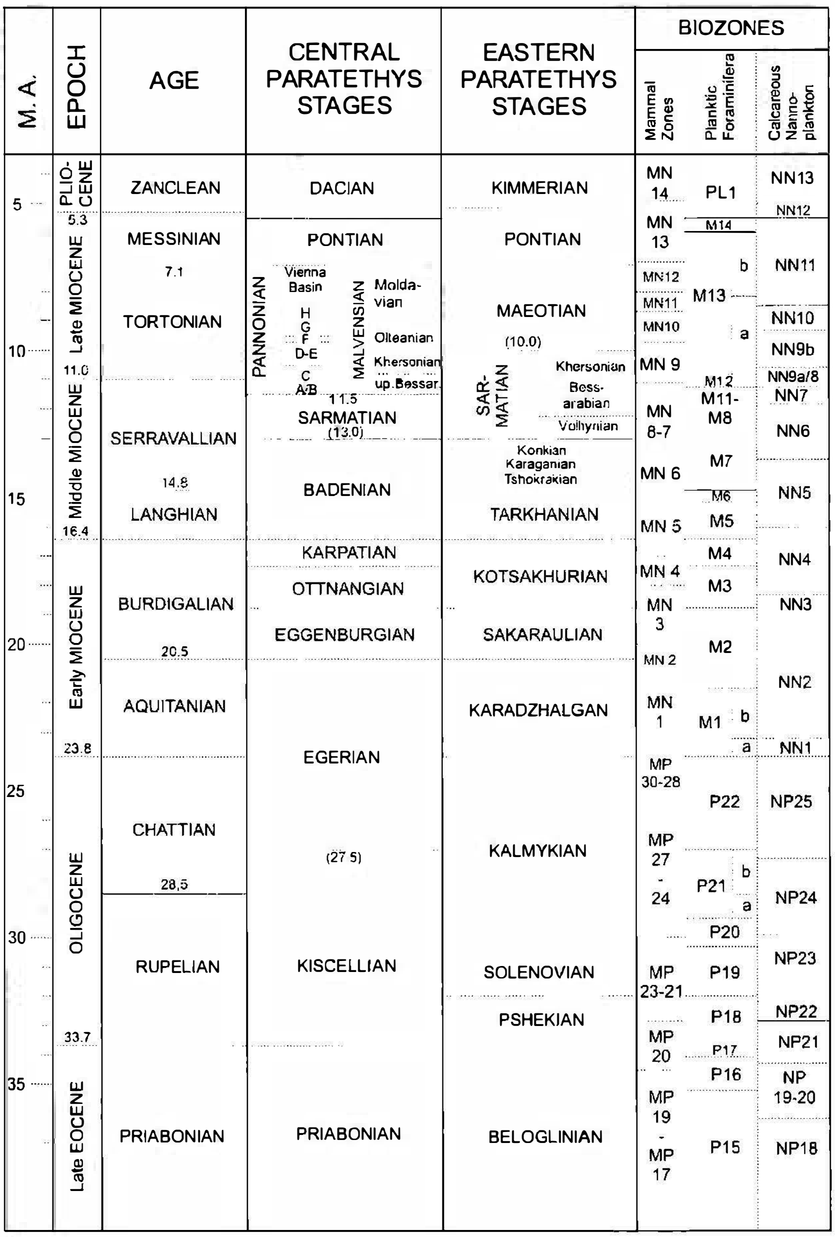

Fig. 1: Correlation of Central and Eastern Paratethys stages (in cooperation with DAXNER-HÖCK and HARZHAUSER; planktic zonation acc. to BERGGREN et al. 1995; mammals acc. to SCHLUNEGGER et al. 1996 and AGUSTÌ et al. 2001; Paratethys acc. to RÖGL 1998).

Aquitanian - Late Egerian - Karadzhalgan (NN1 to lower NN2) (Fig. 2)

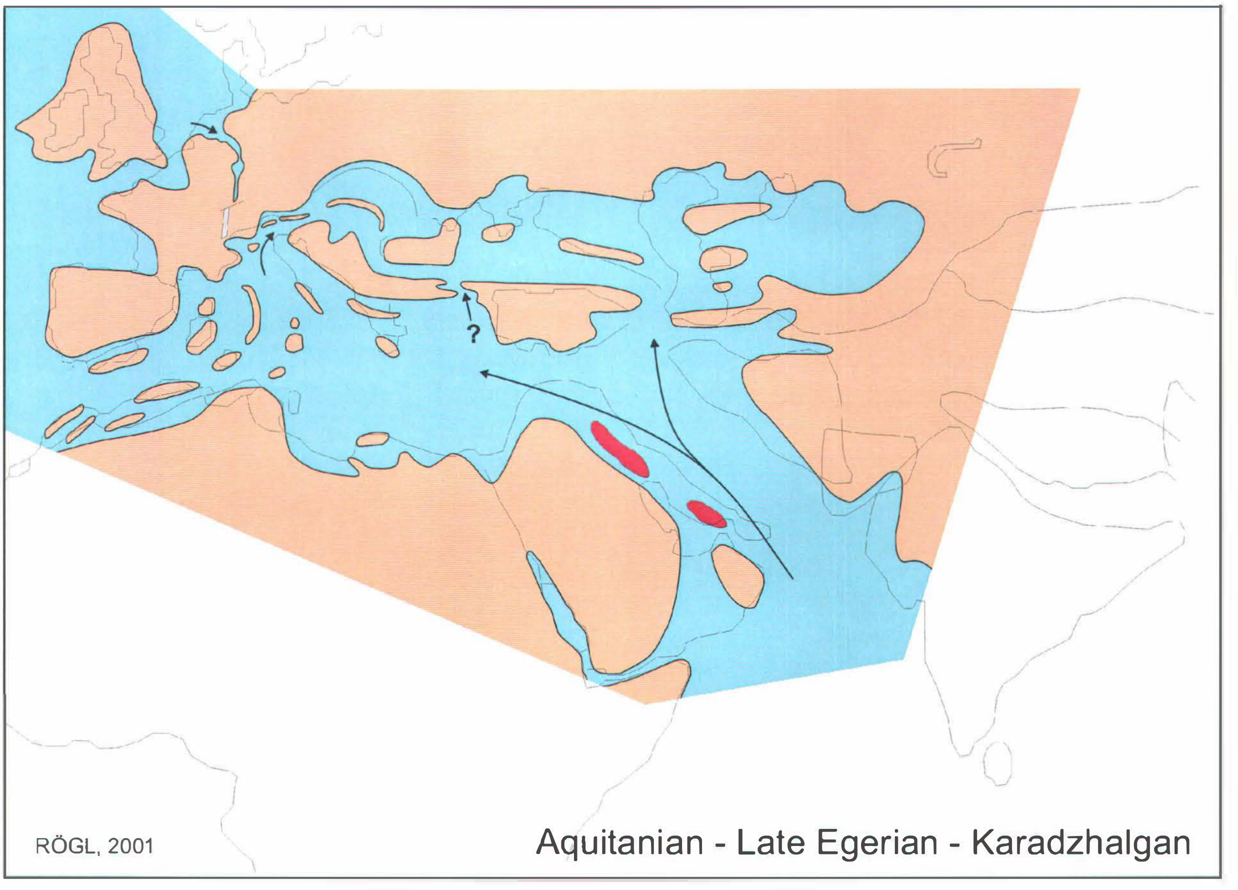

Fig. 2: Paleogeography of Aquitanian - Late Egerian - Karadzhalgan, at 23 Ma.

In the Late Oligocene (nannoplankton zone: upper NP25) marine connections between the Paratethys and the Iranian basins were restored. Similar mollusc faunas and tropical larger foraminifera appear from the Qom Basin (Iran) to the Mediterranean (e.g., Mesohellenic Basin), and to the Central Paratethys (northern Hungary-southern Slovakia). Typical larger foraminifera are lepidocyclinas, miogypsinids, and *Cycloclypeus*; altogether about 10 species in the Central Paratethys (BALDI et al. 1999). According to JONES (1999) the number of species of Aquitanian larger foraminifera in the northern Mediterranean and southern Europe was 15, in Southeast Asia 27, but only 4 in East Africa. The distribution reflects current systems in the Indian Ocean and the Mediterranean. In Karadzahlgan time warm water immigrants, similar to those of the Central Paratethys appeared in the Eastern Paratethys (POPOV et al. 1993).

Tectonic activity increased in the Late Oligocene throughout the Mediterranean. The overthrust of the Apennine nappes started in a northeasterly direction and counterclockwise rotation (BOCCALETTI et al. 1990). The Alpine Foredeep was closed since the middle Oligocene, brackish "*Cerithium* Beds" in the Rhine Graben had no exchange with the Paratethys or the Mediterranean (SISSINGH 1998, REICHENBACHER 2000). A connection of the Central Paratethys to the open sea existed through the Slovenian corridor. The conditions in the Molasse Basin make it likely that a second connection existed southward from the Salzburg area to the Po Basin (WAGNER 1996).

Early Burdigalian - Eggenburgian - Sakaraulian (upper NN2 to lower NN3)

Tectonic movements changed the configuration of the Alpine-Carpathian-Dinaride belt with begin of the Burdigalian/Eggenburgian (FODOR et al. 1998). The Western Paratethys Basin opened again along the Alpine chain to connect with the western Mediterranean (SISSINGH 1997). The Slovenian corridor closed. In the Eastern Paratethys, the seaway remained open towards the Indian Ocean.

The Early Burdigalian/Eggenburgian mollusc faunas are similar in the Central Paratethys (from the Bavarian Molasse eastward), in the Eastern Paratethys (Sakaraulian Sea), and in the Qom Basin (Iran). The proposed Indopacific connection as indicated by a horizon of giant pectinids (ADDICOTT 1974, BALDI 1979) is not as well developed in other faunal elements. Otherwise there existed subtropical conditions and Indian elements, e.g., the crocodile *Gavialosuchus* in the bay of Eggenburg (Central Paratethys).

Late Burdigalian - Ottnangian - Early Kotsakhurian (upper NN3 – lower NN4) (Fig. 3)

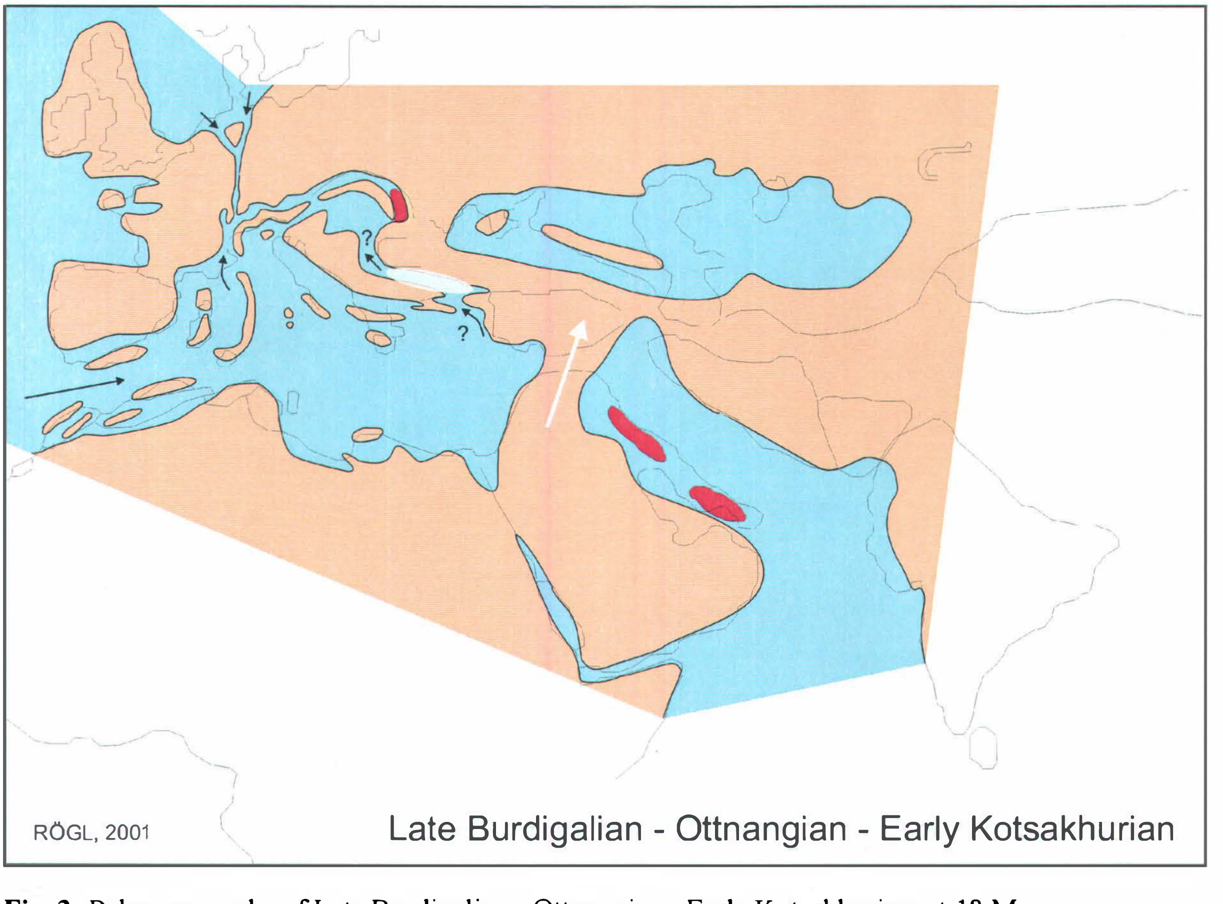

Fig. 3: Paleogeography of Late Burdigalian - Ottnangian - Early Kotsakhurian, at 18 Ma.

The counter-clockwise rotation of Africa and Arabia resulted in a collision with the Anatolian plate. For a first time the Mediterranean was cut off from the Indopacific. The Mediterranean became a giant embayment of the Atlantic. The newly formed landbridge, called the "*Gomphotherium* Landbridge" enabled a continental faunal exchange between South and North. The invasion of proboscideans, e.g., *Gomphotherium* in Eurasia is an indicator for this important event.

These tectonic activities cut off also the Eastern Paratethys from open marine connections, and the endemic Kotsakhurian facies with reduced salinity developed, similar to the modern Caspian Sea. Characteristic are the bivalves *Rzehakia* ("*Oncophora*"), *Cerastoderma*, and

Siliqua. In the eastern part of the Carpathian Foredeep evaporites were deposited in the area of the Ukraine and Romania. Otherwise the Rhine Graben opened again for a shallow connection with the North Sea. The faunas in the Western and Central Paratethys are characterised by boreal and Atlantic influences.

Already at this time problems arise for an eastern marine connection of the Central Paratethys, especially of the Transylvanian Basin with the Eastern Mediterranean. Interestingly, the foraminiferal assemblages of small globigerinas show identical species of the Ottnangian in the Central Paratethys, in North Anatolia around Trabzon, and also in the South, in the Antalya Basin (BIZON et al. 1974).

Latest Burdigalian - Late Karpatian - Late Kotsakhurian (NN4 p.p.) (Fig. 4)

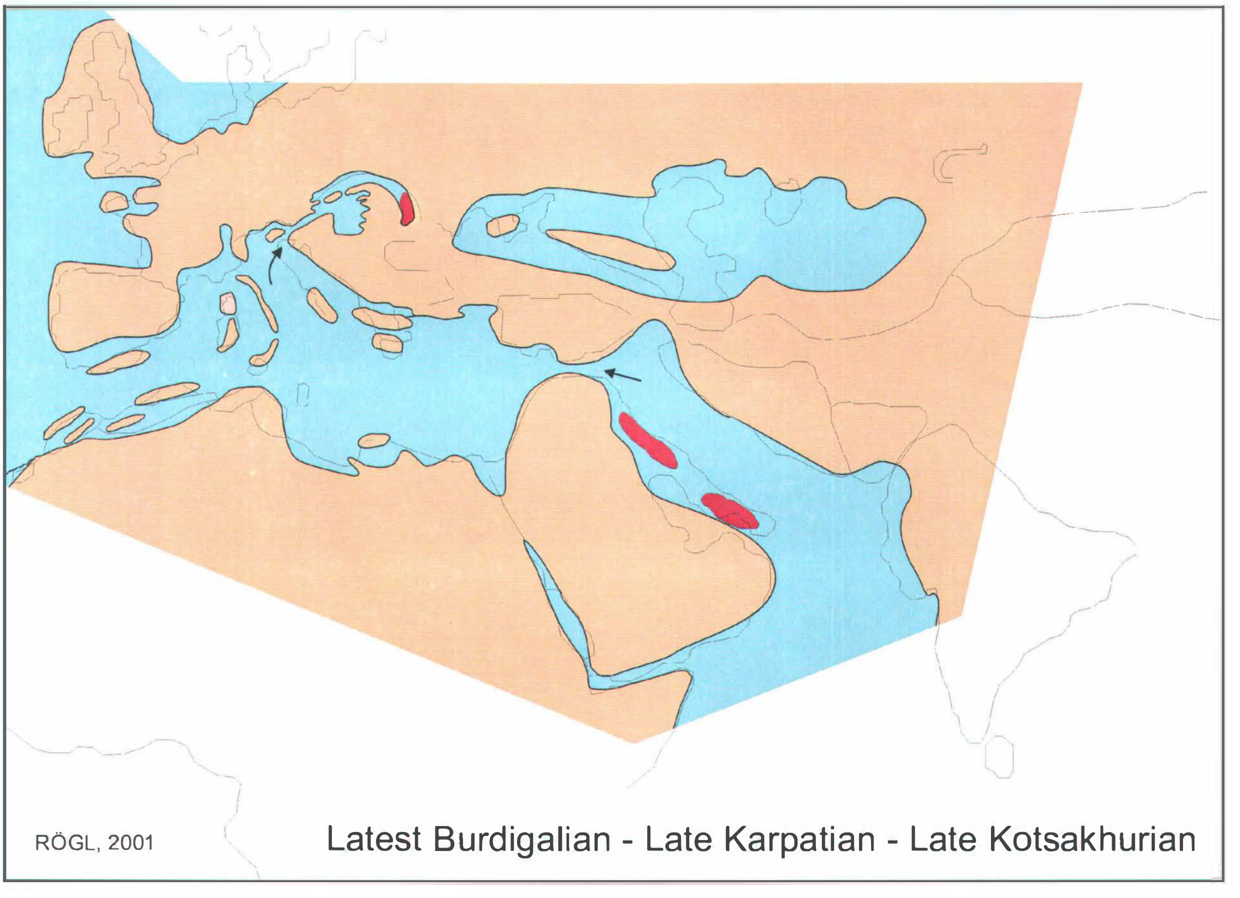

Fig. 4: Paleogeography of latest Burdigalian - Karpatian - Late Kotsakhurian, at 16.7 Ma.

The regional re-organisation came to its peak during the Styrian tectonic phase. By the end of Ottnangian a far spread regression occurred in the Central Paratethys. *Rzehakia* faunas, similar to those of the Kotsakhurian developed in the estuarine areas. A turnover from W-E stretching elongated basins to an intra-mountain basin configuration occurred. During the Karpatian the Alpine Foredeep became dry land, as it was also in the Transylvanian Basin. Microfaunas of the Transylvanian Basin do not yield the Karpatian *Globigerinoides bisphericus* horizon, but show already *Praeorbulina* as indicator of the Middle Miocene.

The Styrian phase was active throughout the Mediterranean and re-opened the marine connection with the Indian Ocean. This opening may have occurred already as early as the latest Burdigalian as indicated by mollusc faunas in the Mut Basin (southern Anatolia). Such subtropical mollusc faunas occur in the Central Paratethys during the Late Karpatian around the *Globigerinoides bisphericus* level. These assemblages are dated paleomagnetically and with micromammals in the Korneuburg Basin (Austria) as 16.3 - 16.7 Ma and MN5 (SCHOLGER 1998, DAXNER-HÖCK et al. 1998). According to our correlation, in the Eastern Paratethys the endemic Kotsakhurian Sea existed furtheron during the Karpatian time of the Central Paratethys.

Langhian - Early Badenian - Tarkhanian (upper NN4 - lower NN5) (Fig. 5)

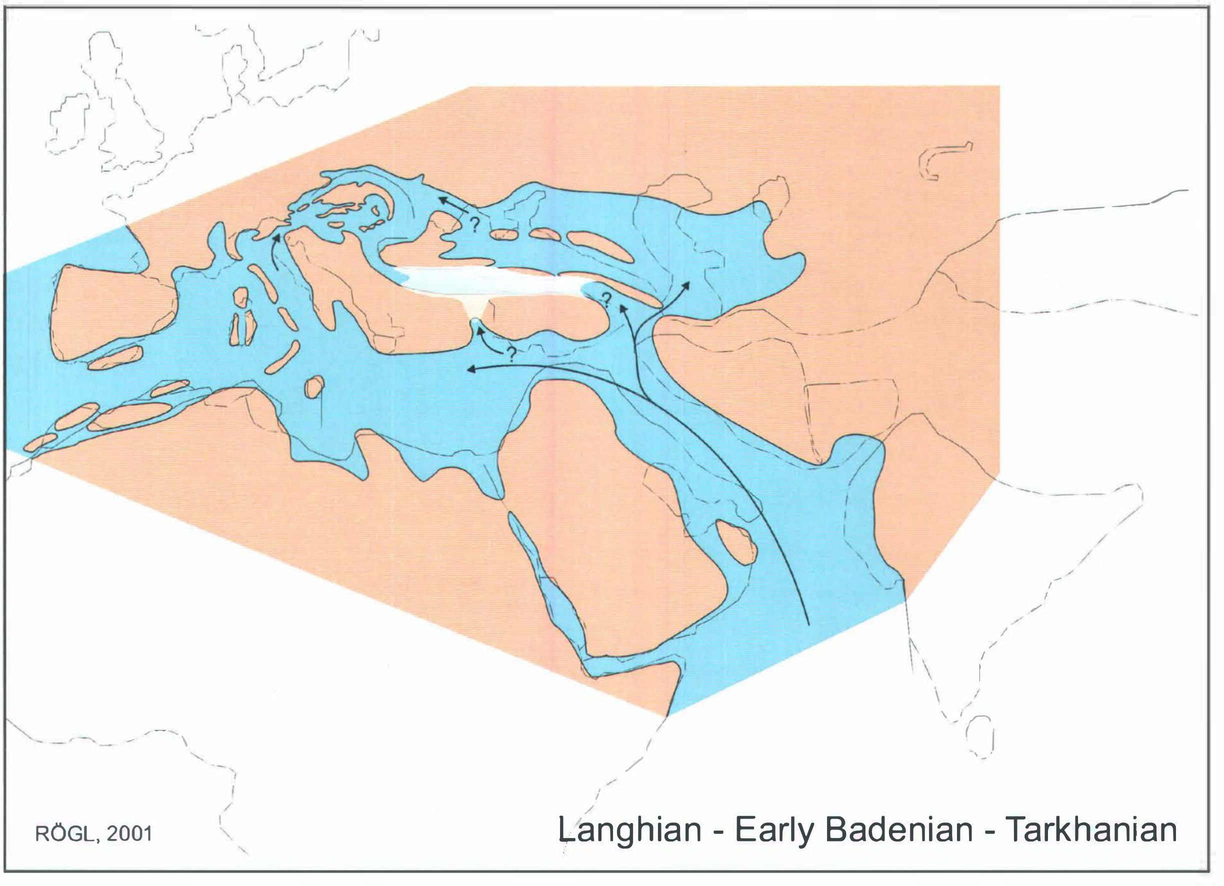

Fig. 5: Paleogeography of Langhian - Early Badenian - Tarkhanian, at 16 Ma.

The Middle Miocene marine corridor between the Indian Ocean and the Mediterranean was open intermittently (JONES 1999). The Central Paratethys communicated by the so-called "Trans-Tethyan-Trench-Corridor" in Slovenia with the Mediterranean. But such a small trench as the single seaway is unlikely as the new transgression covered all the area from the Carpathian Foredeep to the Transylvanian Basin. The best developed marine sedimentation and richest faunas are observed in Transylvania, and around the Iron Gate of the Danube in Romania with pelagic *Globigerina* marls. Marine Miocene sediments are not recorded, to indicate a postulated south-eastern marine seaway along the suture between the Balkanides and the Rhodope Massif.

A northward Eastern Mediterranen - Central Paratethys seaway through the Balkanides (STUDENCKA et al. 1998) is difficult to explain. Marine sedimentation ended in the Aegean and Mesohellenic Basin at the end of Burdigalian. The Aegean mainland came into existence. According to deep drillings in the northern Aegean around Thassos no Middle Miocene sedimentation exists (POLLAK 1979). A connection through the Morava valley in Serbia is not possible, as there are continental deposits. At this time the Serbian lake system covered the Dinarides mainland, from central and eastern Serbia to the SE beyond Skopje in Macedonia (KRSTIC et al. 1996, VUJNOVIC et al. 2000). In the area of Belgrade the Middle Badenian sea transgressed from the north.

Along the North Anatolian Fault we have again the problem of missing marine Middle Miocene sediments. The Black Sea coast of Anatolia belongs already to the Black Sea plate and around Sinop Tarkhanian deposits are present. Therefore a connection south of this fault zone, proposed by RÖGL (1998), stays speculative. But this is one of the open problems, to connect the Central Paratethys by another seaway beside the Slovenian corridor. Probably there has been space in the problematic region, north of the Mediterranean, where paleomagnetic measurements point to a latitudinal 10° shortening since the Early Miocene (KISSEL et al. 1989).

The Kotsakhurian Basin of the Eastern Paratethys was transgressed by the Tarkhanian Sea. Marine sediments in eastern Anatolia point to a seaway in the Lake Van area. The main problem for an eastern marine connection of the Central Paratethys through the Black Sea Basin (RÖGL & STEININGER 1983) is, that the facies of the Tarkhanian Sea is entirely different. The fauna is impoverished in comparison with the Central Paratethys. Bottom conditions are still influenced by hydrogen sulphide contamination. After long discussions, the stratigraphic correlation of the Tarkhanian now is documented by calcareous nannoplankton as zone NN5, and by co-occurring planktic foraminifera *Globigerinoides bisphericus* and *Praeorbulina* cf. *transitoria* (ANDREYEVA-GRIGOROVICH & SAVYTSKAYA 2000).

Early Serravallian - Middle Badenian - Karaganian (upper NN 5 to lower NN 6?)

The open marine seaways to the Indian Ocena did not last long. Movements along the Levante Fault closed again the seaway at the Bitlis suture zone. The Mediterranean became again an Atlantic embayment. In the Paratethys the conditions of the eastern part were changing during the Tshokrakian, and finally the Ponto-Caspian region was sealed off again from open oceans (IL'INA 2000). The endemic brackish Karaganian Sea came into existence. With the begin of the Serravallian regression and the final closure of the Mediterranean seaway to the Indian Ocean a distinct shift in isotopes occurred (FLOWER & KENNETT 1993).

In the Central Paratethys the Leitha phase caused uplifts in the Carpathian arc. Extensive evaporite sedimentation followed in the Carpathian Foredeep and in the Transylvanian Basin. In the area from the Pannonian Basin to the "Trans-Tethyan-Trench-Corridor" in Slovenia marine conditions prevailed.

Early Serravallian - Late Badenian - Konkian (NN6/7) (Fig. 6)

A short lived opening in Eastern Anatolia linked the Indian Ocean and the Paratethys for a last time. A similar facies developed throughout the basins in the Konkian and Kosovian (Late Badenian) time. The Mediterranean connection through the "Trans-Tethyan-Trench-Corridor" in Slovenia was closed (comp. also STUDENCKA et al. 1998).
The problems continue, that also during this event the best developed marine conditions existed in the Transylvanian Basin. On top of the evaporites, radiolaria and pteropod marls were deposited. Indopacific relations of radiolaria and calcareous nannoplankton are distinct (DUMITRICA et al. 1975). In the shallows and along the coast lines small patch reefs and corallinacean limestones (Leitha Limestone) formed in large areas of the Paratethys.

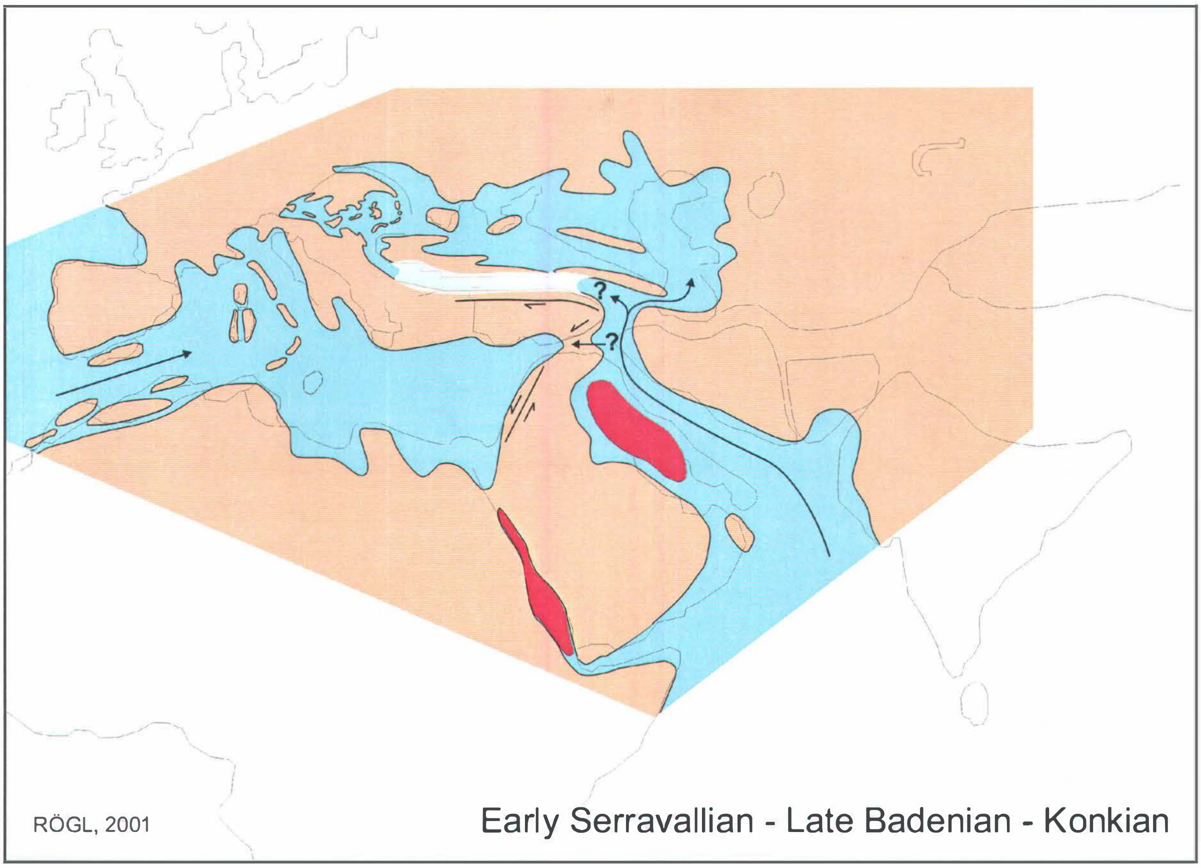

Fig. 6: Paleogeography of Early Serravallian - Late Badenian - Konkian, at 13.5 Ma.

Middle Serravallian - Early Sarmatian - Volhynian (NN7/8) (Fig. 7)

A new configuration of the Circum-Mediterranean area developed in the Middle Serravallian-Sarmatian time. Indopacific connections were closed. But along the East Anatolian Transform Fault opened a new narrow seaway. From the Mediterranean along the upper Euphrates valley marine connections existed into the Araks Basin in Armenia and to the Transcaspian Basin.
During the Sarmatian time all stenohaline forms as corals, echinoids, and planktic foraminifera became extinct in the Paratethys. According to PISERA (1996) it is not only a reduction in salinity but more important a change to higher alkalinity.

Middle Tortonian - Pannonian - Maeotian (NN9-11) (Fig. 8)

The Aegean Sea opened along tectonic graben structures during the Tortonian and connected the Mediterranean and Paratethys along the new seaway of the Marmara Sea. Increasing continentalisation reduced the aquatic realm of the Central Paratethys to the Pannonian Lake within the Carpathian arc and brought about a regression from the Carpathian Foredeep.
The Eastern Paratethys facies extended westward in the Dacian Basin. During the Bessarabian and Khersonian brackish conditions existed similar to the Sarmatian in the Vienna Basin, with a bloom of the bivalve *Mactra*. This is the cause for the different use of the term Sarmatian in the Eastern Paratethys. After a strong regression and isolation in the Late Khersonian, a new transgression occurred in the Black Sea region with the Maeotian (KOJUMDGIEVA 1983). This transgression is connected with the Tortonian transgressive highstand.

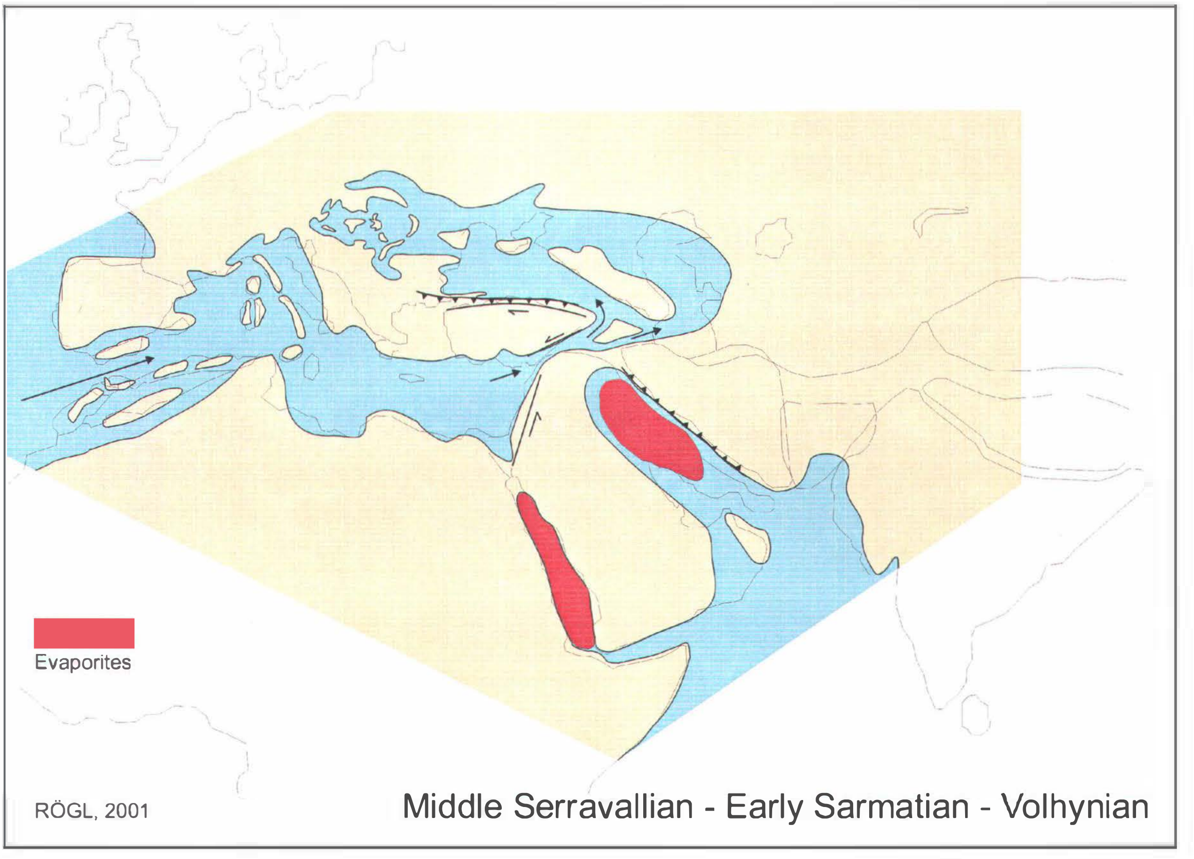

Fig. 7: Paleogeography of Middle Serravallian - Early Sarmatian - Volhynian, at 13 Ma.

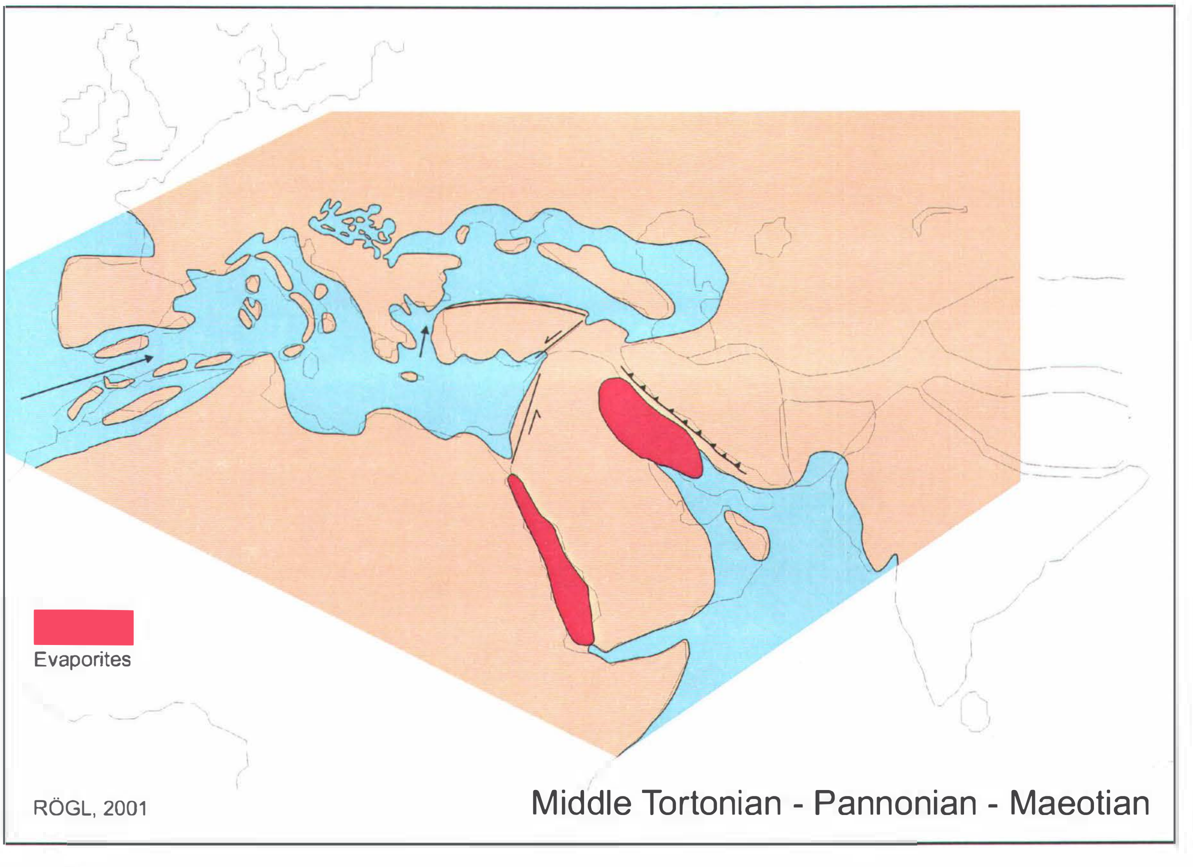

Fig. 8: Paleogeography of Middle Tortonian - Pannonian - Maeotian, at 10 Ma.

In Pontian time a facies of strongly reduced salinity with an endemic fauna spread from the Pannonian Basin over all the Eastern Paratethys basins. This Pontian Lake extended southward into the Aegean Basin and as the "Lago Mare" facies into the Mediterranean Basin (RÖGL et al. 1991, POPOV & NEVESSKAYA 2000). The reason of the new isolation can be seen in the Messinian regression and evaporation of the Mediterranean.

The Pliocene transgression with deeper water sediments of Trubi marls, on top of evaporites and freshwater "Lago Mare" facies formed the modern Mediterranean Sea.

References

ADDICOTT, W., 1974: Giant pectinids of the eastern North Pacific margin: Significance in Neogene zoogeography and chronostratigraphy. - Journal Paleont., 48, 180-194, Tulsa.

AGUSTÍ, J., CABRERA, L., GARCES, M., KRIJGSMAN, W., OMS, O. & PARES, J.M., 2001: A calibrated mammal scale for the Neogene of Western Europe. - Earth Sci. Rev., 52, 247-260, Amsterdam.

ANDREYEVA-GRIGOROVICH, A.S. & SAVYTSKAYA, N.A., 2000: Nannoplankton of the Tarkhanian deposits of the Kerch Peninsula (Crimea). - Geol. Carpathica, 51/6, 399-406, Bratislava.

BALDI, T., 1979: Changes of Mediterranean/?Indopacific/ and boreal influences on Hungarian marine molluscfaunas since Kiscellian until Eggenburgian times; the stage Kiscellian. - Ann. Geol. Pays Helleniques, t. hors ser. 1979, fasc.I: 39-49, Athens.

BALDI, T., LESS, G. & MANDIC, O., 1999: Some new aspects of the lower boundary of the Egerian stage (Oligocene, chronostratigraphic scale of the Paratethys area. - Abh. Geol. Bundesanst., 56/2, 653-668, Wien.

BERGGREN , W.A., KENT, D.V., SWISHER, C.C. & AUBRY, M.-P., 1995: A revised Cenozoic Geochronology and Chronostratigraphy. - In: BERGGREN, W.A., KENT, D.V. & HARDENBOL, J., (eds.): Geochronology, Time Scales and Global Stratigraphic Correlations: A Unified Temporal Framework for a Historical Geology. - SEPM Special. Publ., 54, 129-212, Tulsa.

BIZON, G., BIJU-DUVAL, B., LETOUZEY, J., MONOD, O., POISSON, A., ÖZER, B. & ÖZTÜMER, E., 1974: Nouvelles précisions stratigraphiques concernant les bassins Tertiaires du sud de la Turquie (Antalya, Mut, Adana). - Revue Inst. Francais Pétrole, 29/3, 305-325, Paris.

BOCCALETTI, M., CIARANFI, N., COSENTINO, D., DEIANA, G., GELATI, R., LENTINI, F., MASSARI, F., MORATTI, G., PESCATORE, T., RICCI LUCCHI, F. & TORTORICI, L., 1990: Palinspastic restoration and paleogeographic reconstruction of the peri-Tyrrhenian area during the Neogene. - Palaeogeography, Palaeoclimatology, Palaeoecology, 77/4,1-50, Amsterdam.

DAXNER-HÖCK, G., HAAS, M., MELLER, B. & STEININGER, F.F., 1998: Wirbeltiere aus dem Unter-Miozän des Lignit-Tagebaues Oberdorf (Weststeirisches Becken, Österreich). 10. Palökologie, Sedimentologie und Stratigraphie. - Ann. Naturhist. Mus. Wien, 99A, 195-224, Wien.

DUMITRICA, P., GHETA, N. & POPESCU, G.H., 1975: New data on the biostratigraphy and correlation of the Middle Miocene in the Carpathian area. - Dari Seama Sedint., Inst. Geol. Geofiz., 61 (1973-1974)/4, Stratigrafie, 65-84, Bucuresti.

FLOWER, B.P. & KENNETT, J.P., 1993: Middle Miocene ocean-climate transition: high-resolution oxygen and carbon isotopic records from Deep Sea Drilling Project Site 588A, Southwest Pacific. – Paleoceanography, 8/4, 811-843, Washington D.C.

FODOR, L., JELEN, B., MARTON, E., SKABERNE, D., CAR, J. & VRABEC, M., 1998: Miocene-Pliocene tectonic evolution of the Slovenian Periadriatic fault: implications for Alpine-Carpathian extrusion models. – Tectonics, 17/5, 690-709, Washington D.C.

FORNACIARI, E., RIO, D., GHIBAUDO, G., MASSARI, F. & IACCARINO, S., 1997: Calcareous plankton biostratigraphy of the Serravallian (Middle Miocene) stratotype section (Piedmont Tertiary Basin, NW Italy). - Mem. Sci. Geol., 49, 127-144, Padova.

IL'INA, L.B., 2000: On connections between basins of the Eastern Paratethys and adjacent seas in the Middle and Late Miocene. - Strat. Geol. Correlation, 8/3, 300-305, Moscow.

JONES, R.W., 1999: Marine invertebrate (chiefly foraminifera) evidence for the palaeogeography of the Oligocene-Miocene of western Eurasia, and consequences for terrestrial vertebrate migration. - In: AGUSTÍ, J., ROOK, L. & ANDREWS, P. (eds.): The evolution of Neogene terrestrial ecosystems in Europe. - Hominoid evolution and climatic change in Europe, vol. 1: 274-308, Cambridge Univ. Press, Cambridge-New York.

KISSEL, C., LAJ, C., MAZAUD, A., POISSON, A., SAVASCIN, Y. et al., 1989: Paleomagnetic study of the Neogene formations of the Aegean Sea. - In: SENGÖR, A.M.C. (ed.): Tectonic evolution of the Tethyan region. - NATO ASI, Ser. C 259, 137-157, Kluwer Acad. Publ., Dordrecht-Boston-London.

KOJUMDGIEVA, E., 1983: Palaeogeographic environment during the desiccation of the Black Sea. - Palaeogeography, Palaeoclimatology, Palaeoecology, 43, 195-204, Amsterdam.

KRSTIC, N., STANIC, S., CVETKOVIC, V., ZIC, J. & PETROVIC, D., 1996: Neogene superterranes of Dinarides and Carpatho-Balkanides in SR Yugoslavia. - Mitt. Ges. Geol. Bergbaustudenten Österreich, 41, 115, Wien.

PISERA, A., 1996: Miocene reefs of the Paratethys: A review. - SEPM Concepts in Sedimentology and Paleontology 5, 97-104, Tulsa (SEPM, Society for Sedimentary Geology).

POLLAK, W.H., 1979: Structural and lithological development of the Prinos-Kavala Basin, Sea of Thrace, Greece. - Ann. Geol. Pays Helleniques, t. hors ser. 1979, fasc. 2: 1003-1011, Athens.

POPOV, A.V. & NEVESSKAYA, L.A., 2000: Late Miocene brackish-water mollusks and the history of the Aegean Basin. - Strat. Geol. Correlation, 8/2, 195-205, Moscow.

POPOV, S.V., AKHMET'EV, M.A., ZAPOROZHETS, N.I., VORONINA, A.A. & STOLYAROV, A.S., 1993: Evolution of Eastern Paratethys in the late Eocene-early Miocene. - Stratigraphy Geol. Correlation, 1/6, 10-39, Moscow.

REICHENBACHER, B., 2000: Das brackisch-lakustrine Oligozän und Unter-Miozän im Mainzer Becken und Hanauer Becken: Fischfaunen, Paläoökologie, Biostratigraphie, Paläogeographie. - Courier Forsch.-Inst. Senckenberg, 222, 1-143, Frankfurt a.M.

RÖGL, F., 1998: Palaeogeographic considerations for Mediterranean and Paratethys seaways (Oligocene to Miocene). - Ann. Naturhist. Mus. Wien, 99A, 279-310, Wien.

RÖGL, F., 1999: Mediterranean and Paratethys. Facts and hypotheses of an Oligocene to Miocene paleogeography (short overview). - Geol. Carpathica, 50/4, 339-349, Bratislava.

RÖGL, F., BERNOR, R.L., DERMITZAKIS, M.D., MÜLLER, C. & STANCHEVA, M., 1991: On the Pontian correlation in the Aegean (Aegina Island). - Newsletters Stratigr., 24/3, 137-158, Berlin-Stuttgart.

RÖGL, F. & STEININGER, F.F., 1983: Vom Zerfall der Tethys zu Mediterran und Paratethys. Die neogene Paläogeographie und Palinspastik des zirkum-mediterranen Raumes. - Ann. Naturhist. Mus. Wien, 85A, 135-163, Wien.

SCHLUNEGGER, F., BURBANK, D.W., MATTER, A., ENGESSER, B. & MÖDDEN, C., 1996: Magnetostratigraphic calibration of the Oligocene to Middle Miocene (30-15 Ma) mammal biozones and depositional sequences of the Swiss Molasse Basin. - Eclogae Geol. Helvetiae, 89/2, 753-788, Basel.

SCHOLGER, R., 1998: Magnetostratigraphic and palaeomagnetic analysis from the Early Miocene (Karpatian) deposits Teiritzberg and Obergänserndorf (Korneuburg Basin, Lower Austria). - In: SOVIS, W & SCHMID, B. (eds.): Das Karpat des Korneuburger Beckens. Teil 1. - Beitr. Paläont., 23, 25-26, Wien.

SISSINGH, W., 1997: Tectonostratigraphy of the North Alpine Foreland basin: correlation of Tertiary depositional cycles and orogenic phases. – Tectonophysics, 282, 223-256, Amsterdam.

SISSINGH, W., 1998: Comparative Tertiary stratigraphy of the Rhine Graben, Bresse Graben and Molasse Basin: correlation of Alpine Foreland events. – Tectonophysics, 300, 249-284, Amsterdam.

STUDENCKA, B., GONTSHAROVA, I.A. & POPOV, S.Y., 1998: The bivalve faunas as a basis for reconstruction of the Middle Miocene history of the Paratethys. - Acta Geol. Polonica, 48/3, 285-342, Warszawa.

VUJNOVIC, L., KRSTIC, N., OLUJIC, J., JECMENICA, MIJATOVIC, V. & TOKIC, S., 2000: Lacustrine Neogene of the Dinarides. - Proc. Int. Symp. Geology and Metallogeny of the Dinarides and the Vadar Zone. Collections and Monographs, vol. 1: 197-206, Banja Luka-Sarajevo (Acad. Sci. Arts Rep. Srpska, Dept. Natur. Mathem. Techn. Sci.).

WAGNER, L., 1996: Stratigraphy and hydrocarbons in the Upper Austrian Molasse foredeep (active margin). - In: WESSELY, G. & WACHTEL, W. (eds.): Oil and gas in Alpidic thrustbelts and basins of Central and Eastern Europe. - EAGE Spec. Publ. 5, 217-235, London.

Peri-Tethys Programme: Tertiary palaeogeographical maps

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Altogether 24 palaeogeographical maps have been constructed as part of the 1994 – 2000 Peri-Tethys Project, covering the Late Carboniferous to Pleistocene (DERCOURT et al. 2000). Seven of these maps portray the Tertiary palaeogeographical and environmental settings of the Peri-Tethys domains for the Early Eocene, the early Middle Eocene, the late Early Oligocene, the late Early Miocene, the early Middle Miocene, the mid-Late Miocene and the Middle/Late Pliocene. The Tertiary maps reflect the large-scale inversion which affected the platforms at either side of the African/Apulian – Eurasian convergence zone in response to increasingly effective continent – continent collision. The concurrent tectonic fragmentation caused an increasing palaeoenvironmental and palaeobiogeographical differentiation between various domains of the Tethys and Peri-Tethys realms, which differentiation became particularly pronounced from the Eocene – Oligocene transition onward (origin of the Paratethys). The ensuing history portrays general trends of time-progressive termination of marine as well as terrestrial sedimentation and of regional uplift propagating from the west to the east on the platforms proper and along the Peri - Tethys/Tethys transitional zones. These large-scale developments reflect in part temporal and spatial differences in rates of motion of Africa relative to Eurasia and in the onset of subduction roll-back and slab detachment along the convergent plate boundary. The net-result of the northward motions of the African/Arabian block relative to Eurasia shows that these motions were most pronounced in the east, as expressed by the overall, anti-clockwise rotation of Africa/Arabia, whereas the position of the westernmost part of the northern margin of the African plate relative to Iberia remained fairly stable throughout the Cenozoic. Further interpretations of the time-successive paleogeographical maps also show that episodes of major change in the collision zone proper had clear counterparts on the Peri-Tethys platforms. In the Neogene, such episodes of major change pertinent to the EEDEN programme occurred, for instance, in the late Early Miocene to early Middle Miocene, in the Late Miocene and around the Early – Middle Pliocene transition. The present-day land – sea distribution patterns and the pronounced differences between highly elevated mountain chains and deep basins in the circum-Mediterranean area originated in the course of the Pliocene.

References

DERCOURT, J., GAETANI, M., VRIELYNCK, B., BARRIER, E., BIJU-DUVAL, B., BRUNET, M.F., CADET, J.P., CRASQUIN, S. & SANDULESCU, M., (eds.) 2000: Atlas Peri-Tethys, Paleogeographical maps. - CCGM/CGMW, Paris: 24 maps and explanatory notes: I-XX; 1-269.