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).

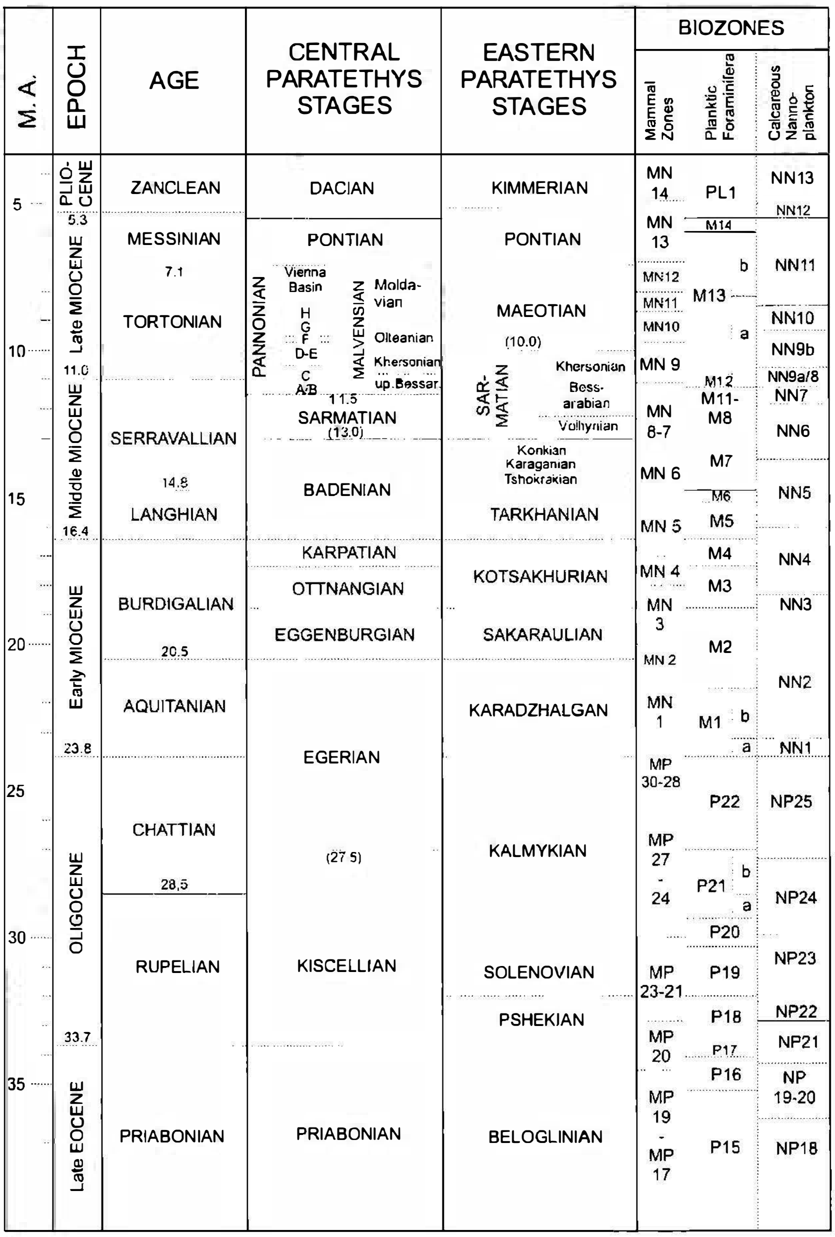

Fig. 1: Correlation of Central and Eastern Paratethys stages (in cooperation with DAXNER-HÖCK and HARZHAUSER; planktic zonation acc. to BERGGREN et al. 1995; mammals acc. to SCHLUNEGGER et al. 1996 and AGUSTÌ et al. 2001; Paratethys acc. to RÖGL 1998).

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

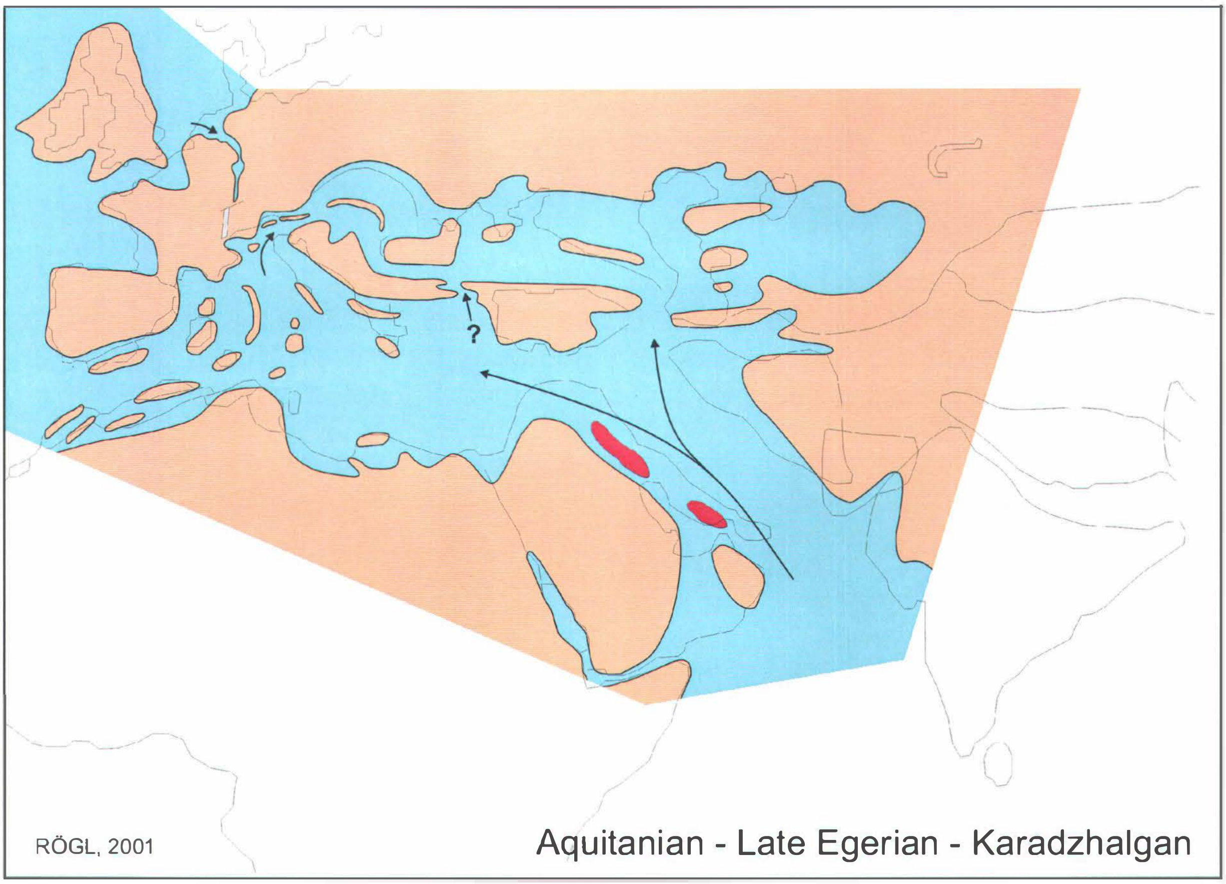

Fig. 2: Paleogeography of Aquitanian - Late Egerian - Karadzhalgan, at 23 Ma.

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)

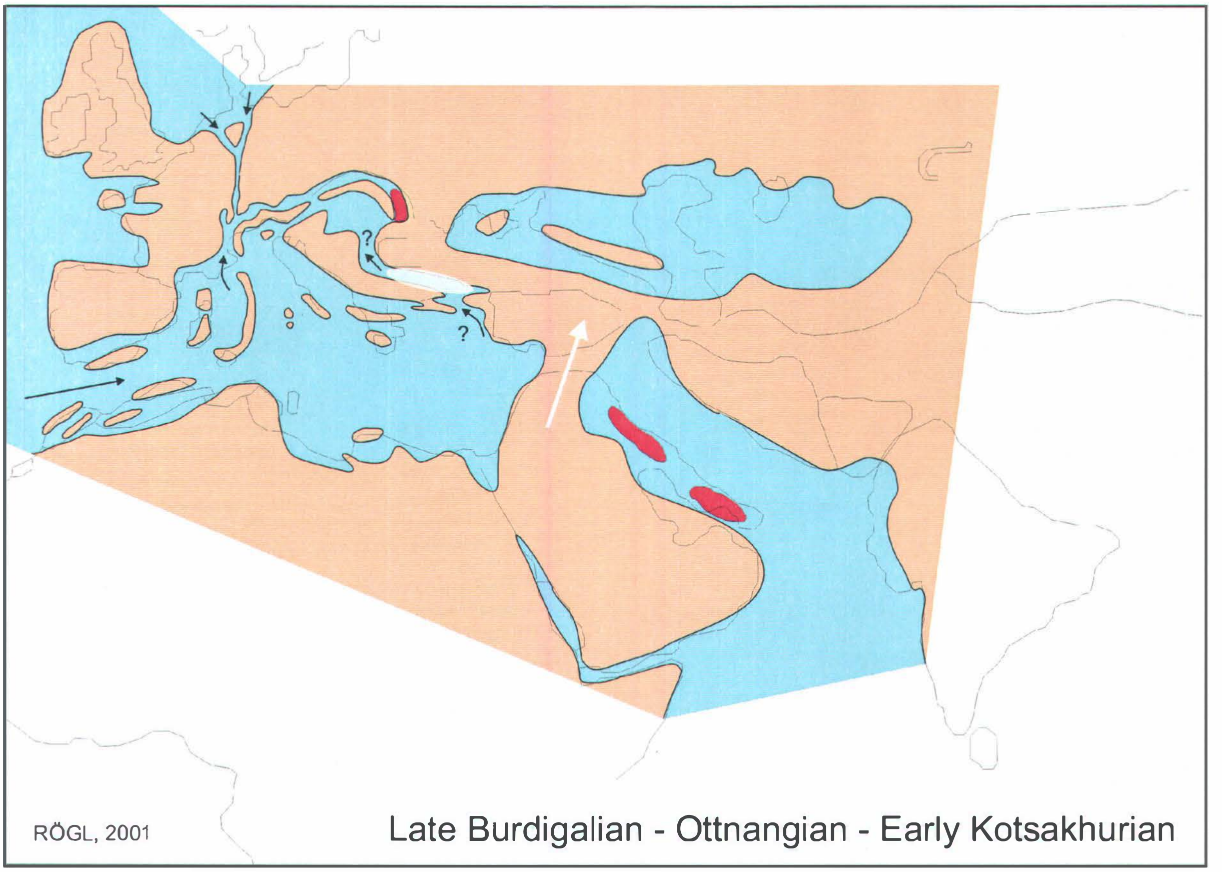

Fig. 3: Paleogeography of Late Burdigalian - Ottnangian - Early Kotsakhurian, at 18 Ma.

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)

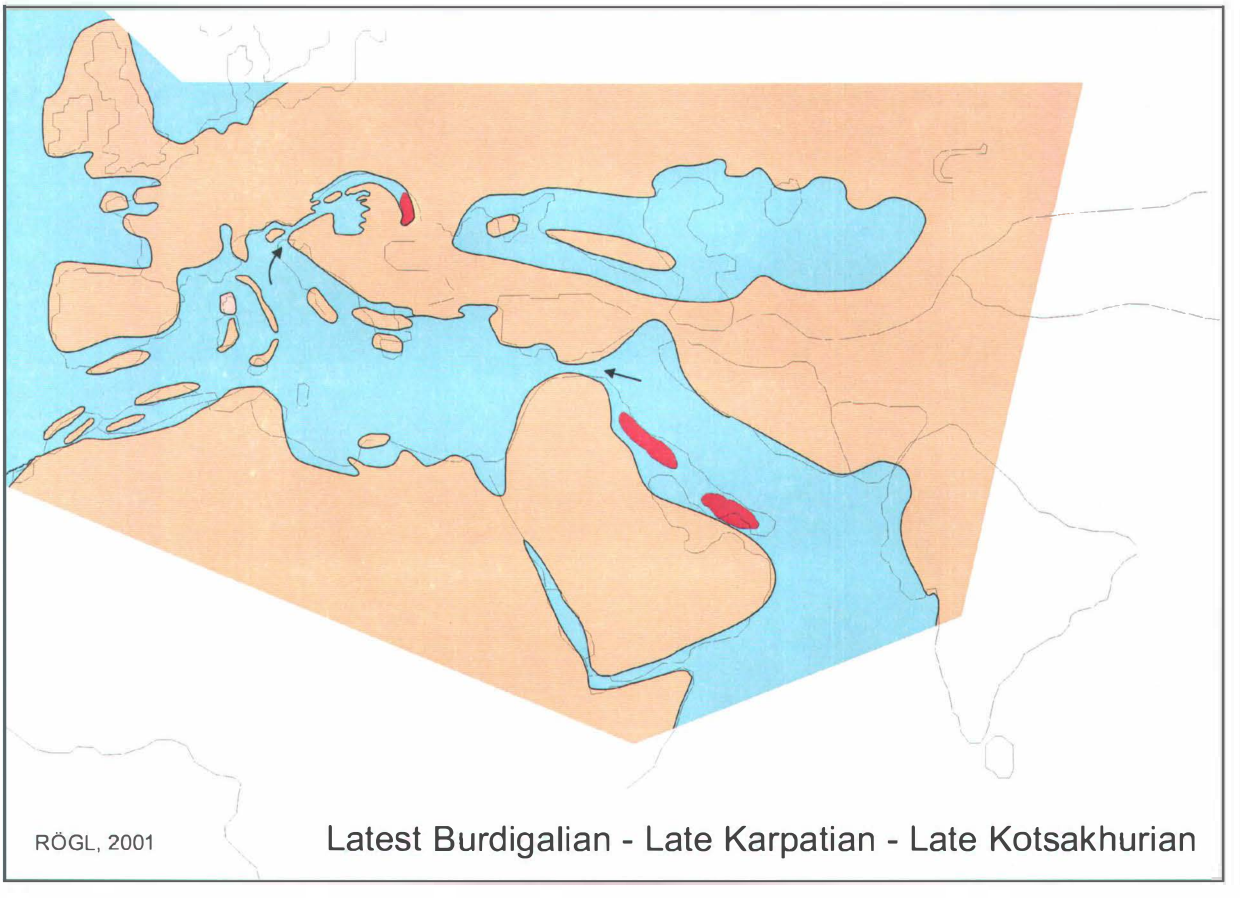

Fig. 4: Paleogeography of latest Burdigalian - Karpatian - Late Kotsakhurian, at 16.7 Ma.

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)

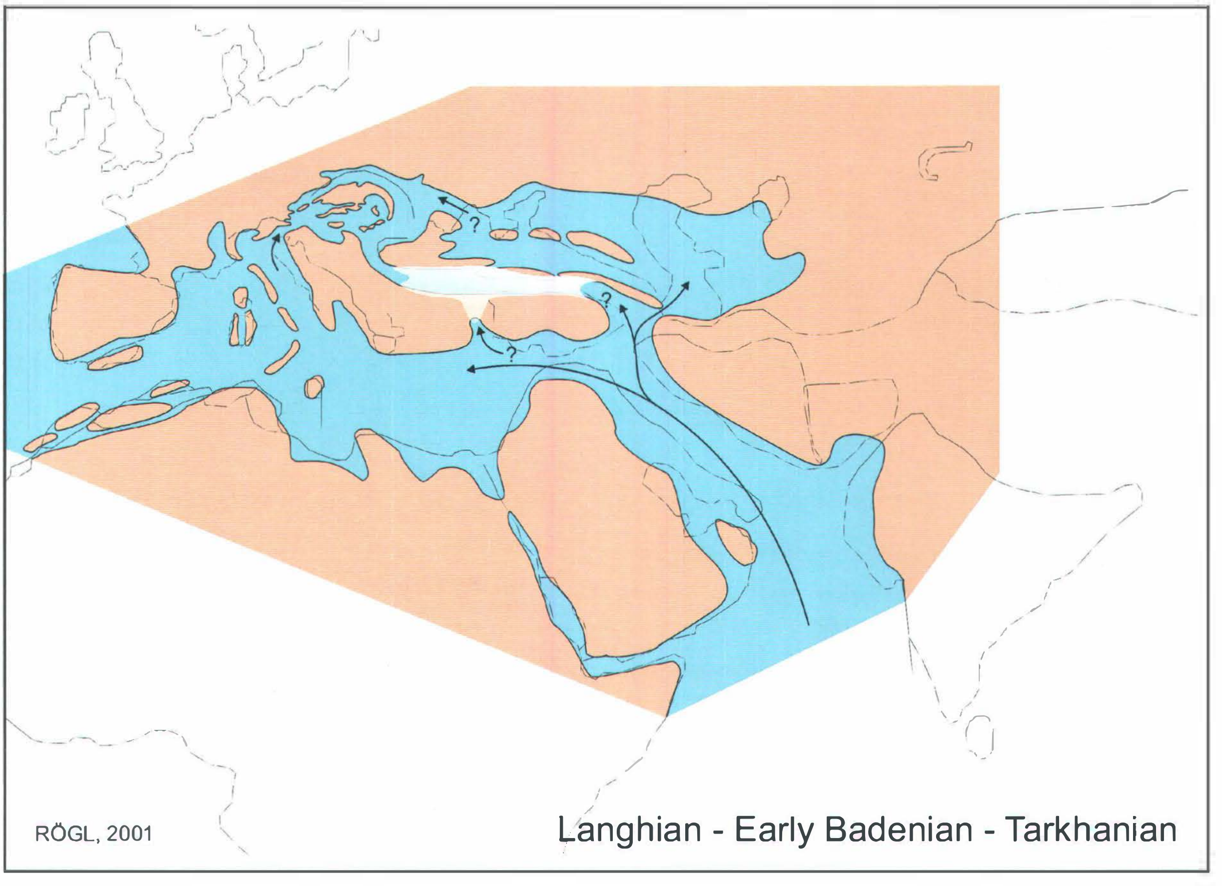

Fig. 5: Paleogeography of Langhian - Early Badenian - Tarkhanian, at 16 Ma.

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.

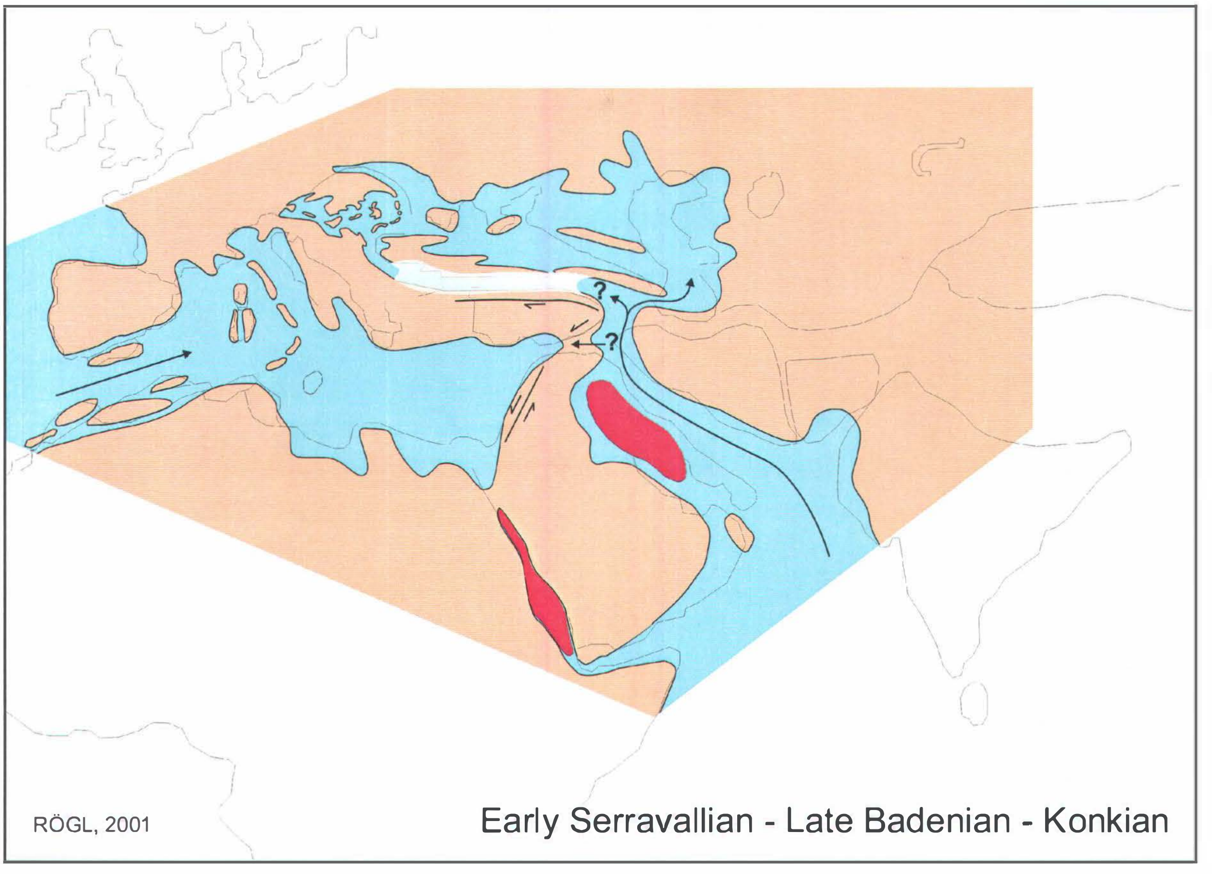

Fig. 6: Paleogeography of Early Serravallian - Late Badenian - Konkian, at 13.5 Ma.

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.

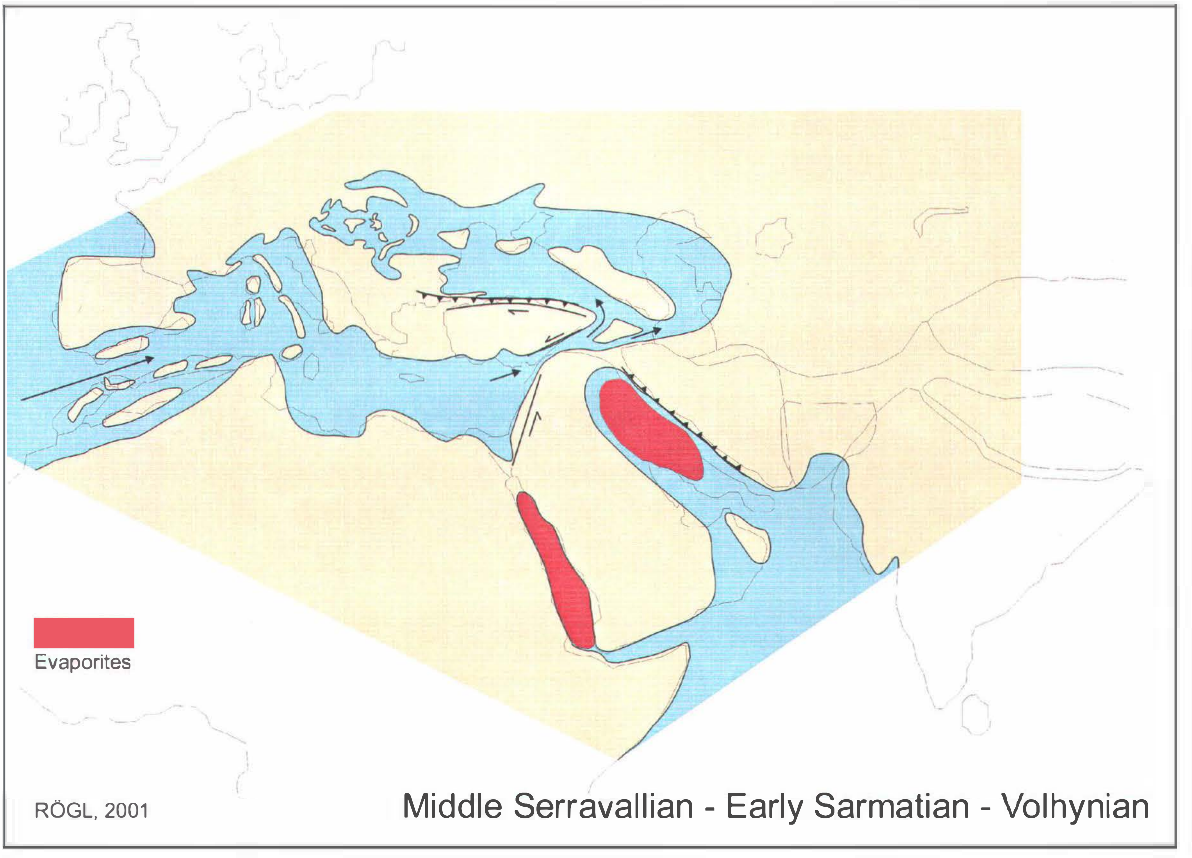

Fig. 7: Paleogeography of Middle Serravallian - Early Sarmatian - Volhynian, at 13 Ma.

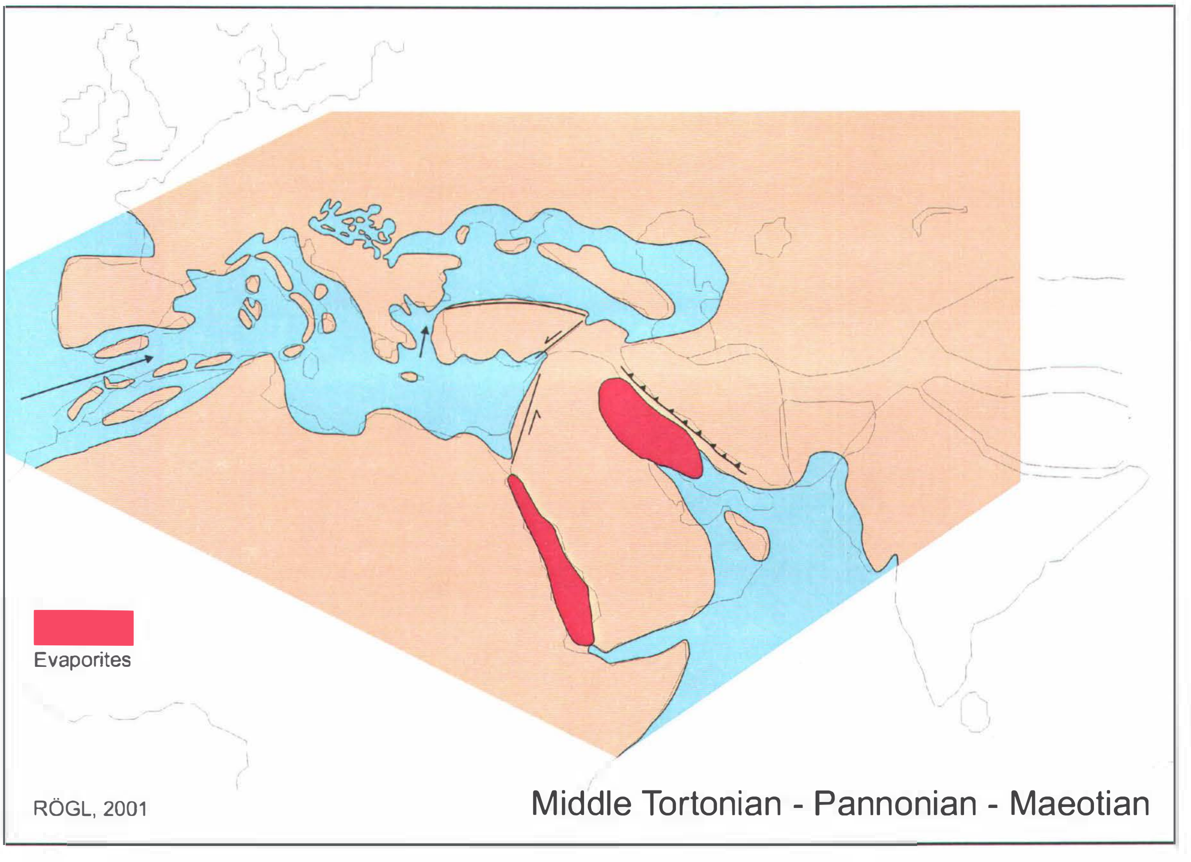

Fig. 8: Paleogeography of Middle Tortonian - Pannonian - Maeotian, at 10 Ma.

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.

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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