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TAMÁS BÁLDI*

TETHYS AND PARATETHYS THROUGH OLIGOCENE TIMES. REMARKS TO A COMMENT

(Figs. 3)

Abstract: The paper stresses biogeographic concept of the Paratethys. The first appearance of endemic fauna was dated at the Earliest Oligocene, the subsequent event was the Neogene Paratethys isolation. The Eastern Paratethys was more or less separated since the occurrence of NP 22—23 nannozone. The Central Paratethys was separated only twice Sarmatian before. The first isolation is referred by the *Ergenica* event (ca. 35 m.y. ago) and the second one is the *Rzehakia* event (ca. 18 m.y. ago). Otherwise the Central Paratethys can be regarded as a "potential bioprovince" for the pre-Sarmatian which was connected with the Tethys.

Резюме: Статья подчеркивает биогеографическую концепцию Паратетиса. Первое появление эндемической фауны датируется с начала олигоцена и изоляция Паратетиса продолжается в неогене. Отделение Восточного Паратетиса можно датировать с появления наннозоны NP 22—23. Изоляцию в Центральном Паратетисе можно наблюдать два раза. На первую изоляцию указывает явление *Ergenica* (35 млн. лет тому назад), на вторую — явление *Rzehakia* (18 млн. лет тому назад). По-другому, Центральный Паратетис можно считать до сармата «потенциальной биопровинцией», которая была связана с Тетисом.

On the basis of a whole array of paleobiogeographic facts, I arrived at the conclusion that the Paratethys existed as early as the Oligocene (Báldi, 1979, 1980, 1984, 1986). Cicha—Krystek (1987) have rejected this conclusion on a sedimentologic—tectonic ground not explained in details in their valuable, but too short paper. As far as I understand, their main arguments are, as follows:

a — "During the Late Oligocene still the sedimentation of flysh and flyshoid sequences took place both in the Carpathians and in the pre-Alpian region." Therefore one cannot speak about the desintegration of "the area of Tethys itself situated on the external side of the forming fold mountains".

conclusion on a sedimentologic-tectonic ground not explained in details nilites are differing much from the "Fischschiefer" and Tard Clay facies, since they are diatomitic. There are younger menilites too.

c — Only during the "Savian movements" became the Alp-Carpathians "isolated" from the deep-ocean "spaces of Tethys rests" This is the right datum for the birth of the Paratethys.

Answering the above questions is a good opportunity to reconsider our basic ideas about the concept of the Paratethys. This concept is not unambiguous. The following main interpretations may be existing.

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* Dr. T. Báldi, Department of Geology, Loránd Eötvös University, Muzeum krt 4/A, 1088 Budapest.

1. The Paratethys is a paleogeographic concept, which is bound to a definite stage of the geosynclinal cycle, namely to the first occurrence of molassic sediments in the fore-deeps. This opinion restricts Paratethys to a single group of sediments and to a few tectonic structures. Cicha—Krystek (1987) stands near to this view.

2. The Paratethys is first of all a biogeographic concept. Its separation from the northern marginal parts of the Tethys is indicated by the sudden evolution and dispersal of endemic faunas. The degree of endemism reflects the effectiveness of separation. Paratethys is a bioprovince clearly distinguishable both from the Tethyan and from the North Sea provinces. In this sense - which is my own image about the Paratethys - this inland sea might have covered very different crustal structures: e. g. the Russian Platform, both the turbiditic and hemipelagic slopes or abyssal plains of the Carpathians and Alps, furthermore fore-deep depressions, back-arc tensional areas, tensional basins of active margins, etc. Flysch might be deposited in the Paratethys (e. g. Krosno Sandstone) and I dont see, why molasse sedimentation would indicate a Paratethyan separation. Fauna is

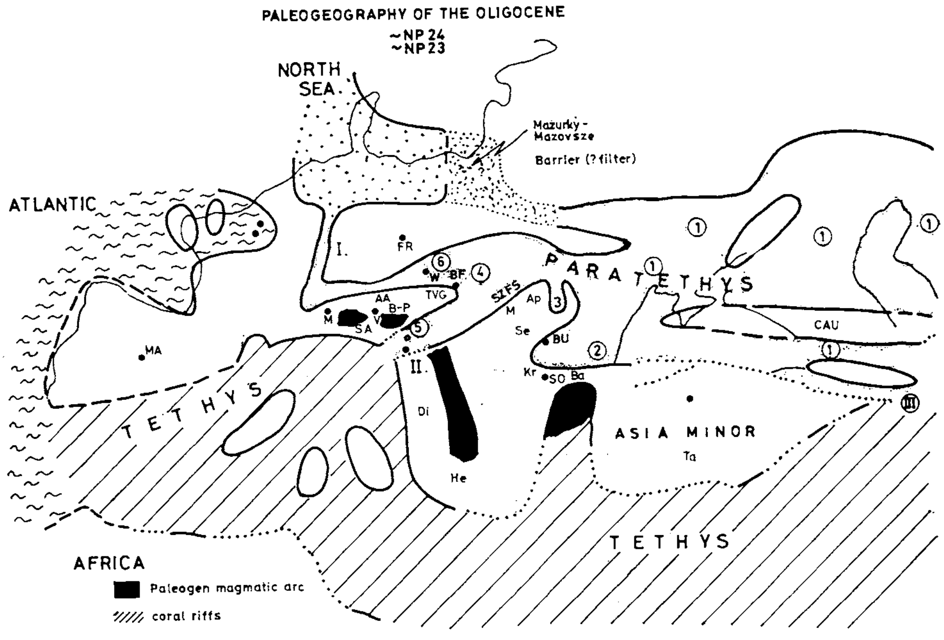

Fig. 1. A palinspastic paleogeographic map of Europe for Oligocene times. *Explanations:* numbers 1—6 are main localities of the *Ergenica* fauna (more see in text). AA - Austro-Alpine Unit; B-P - Bakony-Pilis unit; SA - Southern Alps; SzFS - Szolnok Flysh; M - Mecsek Unit; Ap - Apuseni Unit; Kr - Kraistids, Ba - Balkanides; Di - Dinarides; He - Hellenides; Ba - Balkanides; Ta - Taurides, CAU - Caucasus. I - The Rhine Graben marine straight; II - straight towards the Tethys through N-Croatia and Slovenia; III - a very improbable passage toward the Indopacific.

more sensible to paleogeographic changes than the occurrence of dimly defined rock-associations, like the molasse.

Moreover, it is not enough to restrict ourselves to the study of the Carpathian—Alpine foreland, however important this area is. For tracing Paratethyan boundaries both in time and in space, we have to take into consideration other territories of Northern Tethyan marginal regions.

Relying upon paleontologic criteria, we can discover the pattern of an old, Oligocene Paratethys, occupying about the same area, as the Neogene one (Fig. 1). The endemic *Ergenica cimlanica* fauna is the best indicator of the contours of the Oligocene Paratethys. Moreover, the first occurrence of this endemic mollusc-association dates the time of the first separation. I shall summarize in the first section of the present paper the data concerning the *Ergenica cimlanica* fauna.

Dispersal of the Ergenica cimlanica fauna

On Fig. 1. the distribution of the *Ergenica cimlanica* fauna is shown. The main areal and the group of localities are numbered. In the following I introduce in a very simplified way these occurrences.

1. The Southern Soviet Union (basin around the Black Sea, N and S of the Caucasus, the region of the Caspian Sea, Ustiurt, the Priaral area, etc.). It was recognized still in the early sixties that there is an endemic molluscfauna of "Middle Oligocene" age here and that this fauna is bound to a synchronous level, named "Solenoi Horizon" (Merklin, 1961, 1962).

After and up to date survey of the Solenoi Horizon mollusc fauna (Popov—Ilina—Nicolaeva, 1985), 1 group into three categories the taxa on the basis of their endemism:

a — Endemic genera and species: *Janschinella garetzki* MERKLIN, *J. vinogrodskii* MERKLIN, *J. melitopolitana* NOSSOVSKY, *Lenticorbula sokolovi* KARLOV, *L. mefferti* TITOVA, *L. subtriangula* MOISESCU, *Merklinicardium apostolovense* POPOV, *M. acanthoides* POPOV, *Korobkoviella kiktenkoi* MERKLIN, *K. achalcichensis* MERKLIN, *Rzehakia usturtensis* POPOV, *Ergenica cimlanica* POPOV, *Urbnisia lata* GONTSCHAROVA.

b — Endemic species (cosmopolitan genera): *Cerastoderma mutabile* POPOV, *C. anadaraformicum* POPOV, *C. zhuzhunae* POPOV, *C. serogosicum* NOSSOVSKY.

c — Cosmopolitan taxa (mostly in Upper Solenoi): *Congeria brardii* BRONGNIART, *C. tenuissima* MOISESCU, *C. basteroti* DESH., *Polymesoda convexa brongniarti* BAST. (very rare), *Theodoxus crenulatus* KLEIN, *Melanoides fasciata* SOWERBY, *Brotia escheri* BRONGNIART, *Melanopsis impressa hantkeni* HOFFMANN, *Valvata* sp., *Pomatias* sp. (continental), *Melanopsis sp.*, *Lymnaea* sp., *Physa* sp.

All of the cosmopolitan taxa could have arrived through rivers! One of them is subaerial (continental).

After nannozonation the above assemblage can be found in nannozone NP 23 (Nagymarosy, 1988).

2. Ezerovo Formation (High Thracian Basin in the Srednegorie unit of the Balkanides, Bulgaria) published first time by Kojumdgieva

— Sapundgieva (1981). More or less laminitic marls of 150—230 m thickness are known only from boreholes. Lower part of the Ezerovo Formation is of "Eocène terminal et Oligocène inferieur" on the basis of foraminifera. The middle part of the Formation contains: *Loxocardium lipoldi* ROLLE (e) = endemic, *Nucula comta* GOLDFUSS, *Janschinella garetzkii* MERKLIN (e), *J. melitopolitana* NOSSOVSKY (e), rarely: *Parvicardium scobinula* MERIAN, *Lenticorbula sokolovi slussarevi* MERKLIN (e), *Cerastoderma (Bessia)* merklini KOJUMDGIEVA et SAPUNDGIEVA (e).

The upper part of the Ezerovo Formation yielded: *Lenticorbula sokolovi* KARLOV (e), *Parvicardium popovi* KOJ. et SAP. (e), *Cerastoderma serogosicum* NOSSOVSKY (e), *C. chersonensis* NOSSOVSKY (e), *C. (Bessia) pseudosarmaticum* KOJ. et SAP. (e), *Tellina nysti* DESH., *Siliqua nysti* DESH., *S. asulcata* HÖLZL (e), *Lenticorbula samodurovi* MERKLIN (e), *L. helmerseni transylvanica* MOISESCU (e), *Janschinella garetzkii* MERKLIN (e), *J. melitopolitana* NOSSOVSKY (e), *Congeria kochi* ANDRUSSOV (e), *Congeria euchroma* OPPENHEIM, *Polymesoda convexa brongniarti* BASTEROT, *Lenticorbula helmerseni* MIKHAILOVSKY (e), *Theodoxus crenulatus* KLEIN, *Melanopsis impressa hantkeni* HOFMANN (e), *Abra bosqueti* SEMPER.

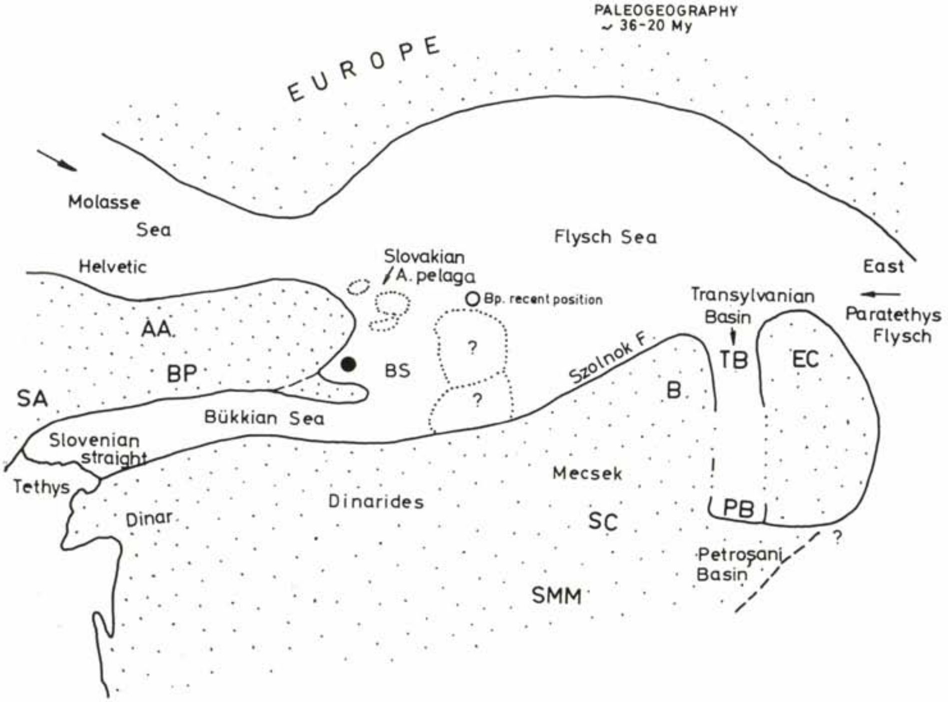

Fig. 2. Palinspastic, paleogeographic map of the Central Paratethys for the Oligocene. *Explanations:* AA - Austro-Alpine; BP - Bakony Pilis; SA - Southern Alps; EC - Eastern Carpathians; B - Bihor-Apuseni; SMM - Serbo-Mazedonian Massif. Black dot is symbolizing the coeval virtual position of Budapest.

There are no nannodata at all. The fauna of the upper part of the Ezerovo Formation with its scattered cosmopolitan elements can be correlated probably with Transylvania's "Cetate Beds", being of Upper Kiscelian, early NP 24 in Moisescu's (1983) and Nagymarosy's (1988) opinion. This seems to be strenghtened by the common, mass occurence of *L. helmerseni* both in the Upper Ezerovo Formation and in the "Cetate Beds". The "Cetate Beds" are coeval with the Kiscell Clay of Hungary.

The middle part of the Ezerovo Formation, with its totally endemic fauna, would be the time-equivalent of the "Creaca" and "Ileanda Beds" of NP 23 in age.

The Solenoi Horizon and the Tard Clay of Hungary are also coeval with the Middle Ezerovo Formation (NP 23 zone, similar endemic fauna).

3. Transylvanian Paleogene Basin: "Creaca", "Bizusa" and "Ileanda Beds" (Rusu, 1983): *Lenticorbula sokolovi* KARLOV (e), *L. helmer-*

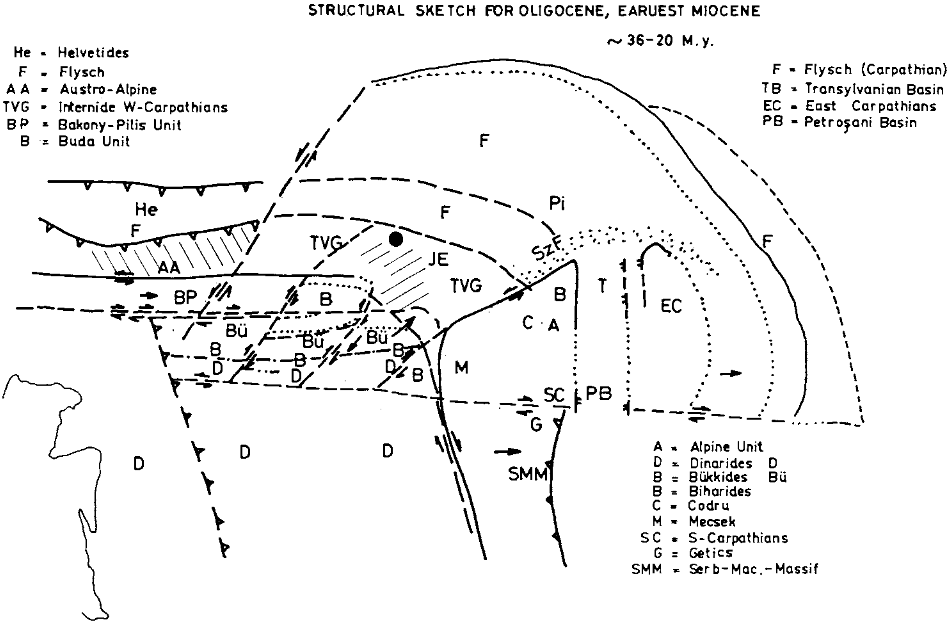

Fig. 3. Proposed tectonic basis of the paleogeographic map on Fig. 2. The basic ideas and data are coming from Báldi (1982, 1986); Royden and Báldi, 1988; Balla, 1987; Kázmér and Kovács, 1985, etc.
Explanation: F - flysch; He - Helvetides; AA - Austro-Alpine Unit; BP - Bakony-Pilis Unit; TVG - Tatro-Vepor-Gemericum; Pi - Pieninic; SzF - Szolnok Flysch; Bü - Bükkian fragments; B - Bihor C - Codru; A - Apuseni; EC - Eastern Carpathian internides; T - Transylvanian Basin; PB - Petrosani Basin; M - Mecsek Unit; SC - S-Carpathians; G - Getics; SMMM - Serbo-Mazedonian Massif; D - Dinaric Units. Note the rotations and strike-slip faulting, which appeared in Miocene. The black circle is the recent, virtual position of Budapest.

seni (MIKHAILOVSKY (e), *L. vinogrodskii* (MERKLIN) (e), *Polymesoda convexa* BRONGNIART, *Cerastoderma serogosicum* NOSSOVSKY (e), *Cardium lipoldi* ROLLE (e), *Congeria brardii* BRONGNIART, *C. nysty* ORB., *C. tenuissima* MOISESCU (e), *Ergenica cimlanica* POPOV (e).

The above assemblage refers "to a pliohaline brackish sea (salinity 9—16.5 pro mille)", "extending from the Carpathians up to Aral Lake region, isolated from Tethys and the Northern realm". "It represents the first temporary separation of the territory which later on - definitively isolated - will become the Paratethys Realm" (Rusu, 1983, p. 33.). At the base of the "Ileanda Beds", Rusu (1983) recognized the "*Nucula comta* level", a marine episod, with boreal — marine fauna (*Nucula comta, Nuculana westendorpi, Tellina nysti, Polinices catena achatensis*, etc.).

After nannozonation: the Bizusa and Ileanda Beds are in NP 23 (Nagymarosy, 1988) nannozone.

4. Tard Clay, Hungary (Báldi, 1979, 1980, 1984, 1986). From bioturbated interlayerings of the laminitic Tard Clay the following molluscfauna has been described from three localities (Budapest—Buda Hills, Cserhát—Felsőpetény, Eger—Kis-Eged): *Cardium (?Loxocardium) lipoldi* ROLLE (e), *Ergenica cimlanica* POPOV (e), *Janschinella melitopolitana* NOSSOVSKY (e), *?Hydrobiidae.*

The fauna is bound to strictly delimited, hardly more than 10 m thick interval of the Lower Tard Clay. Its local distribution was obviously controlled by anoxia (by the euxinic facies). After Nagymarosy (1988) this "*Ergenica*" fauna is in the lowermost part of nannozone NP 23. This occurrence has been correlated also with the magnetostratigraphic scale. Márton P. (in Báldi, 1984) found the fauna in the long reversed phase underlying anomaly 12 (chron 12). After global experience, this interval, the chron 12, is coeval with nannozones NP 22 and lower NP 23 in Martini's sense (Haq—Hardenbol—Vail, 1987), or with planktonic foraminifera zones P 18 and P 19 in Blow's sense.

The molluscfauna is of low diversity, but the few taxa are very abundant within the level of occurrence.

5. "Sotzka Beds", Slovenia, Yugoslavia. We are left to the monograph of Rolle (1858), who figured on his Plate No. 2. *Cardium lipoldi* n. sp. and a "*Trapezium*", which is most probably a *Janschinella.*

I have been strongly suspecting that this fauna is equivalent of the *Ergenica* assemblage (Báldi, 1979, 1980, 1986). "Sotzka Beds" is an obsolete, often misused term after Kušćer (1967). Better known is the Kiscell Clay around Zagorije, yielding an NP 24 nannoflora. The Kiscell Clay is underlain by the "Sotzka Beds", a more or less laminitic marl with marine fish imprints and land-derived macrofloral rests and with a basal coal seam (Cimerman, 1979). The "Sotzka Beds" are most probably identical with Hungary's Tard Clay, both in facies and in age. Strong Miocene folding, the Savian Folds, have been handicapping detailed stratigraphic studies. Earlier dating of the above deformations was erroneous (Oligocene—Miocene boundary). As it was proven by Kušćer (1955), the so called "Sava-Phase" is a post-Sarmatian event.

6. Waschberg-Zone, Lower Austria (Ottenthal). The locality here is still under study. After reviewing the main localities of the *Ergenica cimclanica* fauna, we can draw some general conclusions:

— A low diversity high abundance endemic molluscfauna existed during nannozone Early NP 23, spread over a huge territory. The pattern of the areal perfectly covers that of the later, Neogene Paratethys.

— Endemic taxa were-found also in other groups, even in the nannoplankton too (Nagymarosy, 1988).

— While the *Ergenica* fauna is bound to a low salinity facies and can be found mostly in bioturbated, massive intercalations of otherwise laminitic, euxinic clays and marls, the formations containing this fauna, occur in very different structural units (fore-deeps, back-arc basins, platform, etc.). The assemblage could not invade the deep bathyal environment. *Ergenica* assemblage was not yet found in hemipelagic-pelagic facies. For example, it is unknown so far from the menilites of the Carpathians, though these sediments are partially coeval with the *Ergenica* event.

— The centre of dispersal of the *Ergenica* fauna was in the Eastern Paratethys (S of USSR), because both the degree of endemism and the diversity are highest in this territory. The diversity tends to decline away from the area of origin, furthermore new taxa arise at higher rates in the central region and they spread outward into the margin of the areal - as a generale rule of biogeography (Stehli — Wells, 1971). This explains the rather scattered occurrence of a less diverse *Ergenica* fauna in the Central Paratethys: Hungary, Austria, Yugoslavia, Roumania.

— The duration of existence of the *Ergenica* fauna was rather short, not longer perhaps than one million year.

— In the Eastern Paratethys (including for some time-intervals also Roumania and the Balkanides), no full marine conditions were reestablished after the disappearance of the *Ergenica* fauna. Some degree of endemism survived in Late Kiscellian—Early Egerian times (nannozone NP 24). The endemic taxa were inherited either from the *Ergenica* fauna (e.g. some *Janschinella* species), or they were newly developing (e.g. the *Lenticorbulids*). Also cosmopolitan taxa of Boreal origin occur sporadically with the endemic forms, but on the average, this so called "*Lenticorbula helmerseni* fauna" reflects slight separation of the eastern part from the rest of the Paratethys. Kiscell-type, diverse, rich, cosmopolitan, full-marine faunas are known all over from the Central Paratethyan Late Kiscellian—Early Egerian (NP 24 nannozone), while they are unknown from the Eastern Paratethys.

The problem of barriers

The Paratethys was a restricted area of the Northern Tethys. A belt of mainlands formed a barrier between the two faunal provinces. In Oligocene times the North Sea was covering still considerable parts of stable Europe, therefore barriers between the Boreal and Paratethyan realms must be taken also into consideration.

A barrier is not necessarily perfect. After G. G. Simpson one can recognize different stages in any biogeographic connection from the full scale faunal exchange (corridor) through the imperfect migrational possibilities (filter) until the sweepstake routes, crossing hostile environments, what makes the dispersal chance-like, very rare event (see e.g. Raup — Stanley, 1978). Molluscfaunas of Paratethyan sediments clearly document that the efficiency of barriers was changing on a wide scale both in time and in space. While new corridor was opening at one place, an old corridor became a filter at other place. The corridors were marine straights, disrupting the mainland barriers. The endemism of the Paratethyan faunas was largely depending on the closure of corridors and on the degree of this closure. Filter-like conditions were rather common in those barriers, which were embracing the eastern part of the Paratethys. (E of the Carpathians). For the Central Paratethys the continuity of barriers became constant only in post-Badenian times, (i.e. since Late Serravallian).

The Early Neogene Central Paratethys can be described rather as a "potential bioprovince", which was separated from the Tethys only by a discontinuous belt of mainlands (see the excellent, palinspastic maps of Rögl—Steininger, 1983). This resulted in the flourishing, rich, Tethyan cosmopolitan faunas within the area of the "potential" Central Paratethys. Markedly cosmopolitan faunas were flourishing here during the Eggenburgian (i.e. Early Burdigalian—Late Aquitanian) and in the Early Badenian (i.e. Langhian). Actually only one isolation occurred in the course of Early Neogene times. This event is indicated by the *Rzehakia* fauna (or *Oncophora* fauna) of Late Ottnangian age (i.e. Late Burdigalian) (see Čtyroký, 1972, with good description of the endemic assemblage).

Cosmopolitism was characteristic also for the Oligocene faunas of the Central Paratethys. The diverse and rich faunal assemblages demonstrate immigration both from the Tethys and the North Sea. The occurrence of Boreal elements is a strong evidence for a marine corridor into the North Sea. The intermingling of Tethyan and Boreal taxa is limited, however, for the Oligocene faunas. The appearance of the *Ergenica* fauna about 35 million years ago, in Early Kiscellian (Early Rupelian) times, is the first event referring to a Paratethyan isolation. This event was in many respects similar to the Late Ottnangian *Rzehakia* faunal event (the *Ergenica* genus was described first as "*Oncophora*" or — later — as "*Rzehakia*"). Also the adaptive radiation of the *Cardiids, Congerias,* etc. document the similarity. The two endemic faunas of different age present a classic example of adaptive convergence, what would deserve more attention (see Čtyroký, 1985). Similar environmental stress (most probably lowered salinity), similar paleogeographic pattern (most probably total isolation) triggered converging morphogenetic evolutionary answers of the biotas having existed far away in time (the *Ergenica* fauna is older with 17 million years than the *Rzehakia* fauna). Apart from the *Ergenica* episod, the faunas in the Central Paratethys remained throughout the Oligocene cosmopolitan.

The Eastern Paratethys was — on the other hand — a more closed system during the Oligocene and Early Neogene. Restoration of full-marine conditions, similar to the Central Paratethyan one, did not follow the *Ergenica* event. The Eastern Paratethys remained more or less separated throughout the Oligocene and Neogene. The fauna of this realm could never regain the Tethyan character after the *Ergenica* event (Early Kiscellian about Early Rupelian). Most probably, unstable salinity was responsible for this. Scattered occurrence of cosmopolitan taxa, however, indicate that marine passages breaking through mainland barriers, assured from time to time a filter-like connection with the Central Paratethys and/or also with the Tethys itself. But these connections could not maintain stable salinity. The Eastern Paratethys actually was a more independent bioprovince since Early Oligocene than the Central Paratethys, which latter was isolated only twice before Sarmatian age (Late Serravallian). (The two isolations: the *Ergenica* and the *Rzehakia* events.)

Discontinuities in the frame of barriers were responsible for long lasting cosmopolitism in the Oligocene—Early Neogene Central Paratethyan faunas. Thinking of mainlands, as barriers, one can expect wide and deep straights between the Central Paratethys and other seas for periods of strong cosmopolitism. The straights served as corridors for faunal exchange. Strong tidal effects, tide-dominated shelves and tidal flats can be recognized after sedimentologic criteria on some North Hungarian Egerian and mainly Eggenburgian formations (e.g. Budafok Sands, Pétervására Sandstone, see Báldi, 1959; Báldi et al., in prep.). These observations prove that the tidal wave could enter from the Atlantic through the Tethys into the Central Paratethys during Early Miocene times. The straights were much deeper and wider in those times than the recent straight of Gibraltar (see also Rögl—Steininger, 1983). The strong cosmopolitism of the Eggenburgian fauna indicates also well this fact. Perhaps never so few endemic species arised in the Central Paratethys, as during this age. All these evidences are against the proposal of Cicha—Krystek (1987), who want to date the initiation of the Paratethys right at the beginning of the Eggenburgian.

The efficiency of the barriers and the corridors for hindering or promoting faunal exchange, was controlled by local tectonic (isostatic) crustal movements, or by eustasy. During the Oligocene, the Paratethyan barriers toward the North Sea were dominantly under the control of eustasy, since they were located in stable, consolidated Europe. Corridors towards the Tethys were influenced mainly by local tectonic processes (subduction zones, underplatings, underthrustings creating isostatic readjustments).

The Northern connection

The Paleogene North Sea covered large areas in Middle and Eastern Europe. At the time of occurrence of the *Ergenica* fauna, the extension of the North Sea was still considerably larger than presently or in the Neogene. Mollusc-faunas of the Oligocene Central Paratethys areas show significant Boreal influence. Therefore revisiting of possible corridors from the North Sea, seems to be desirable.

Three possibilities deserve consideration: Turgai Straight, Poland and the Rhine Graben.

The Turgai Straight is located W of the Urals, but marine sediments, younger than Eocene, are unknown from this depression. Nevesskaya et al. (1987) did not indicate on their paleogeographic sketch the Turgai Straight as marine area for Oligocene times. Nevertheless the youngest marine formation is not accurately dated from the Turgai Straight, therefore we can not exclude the presence of Earliest Oligocene nannozones, as NP 21, 22. Cavelier's (1979) paleogeographic map figures a marine Oligocene passage on the place of the Turgai, most probably erroneously for the major part of the Oligocene.

We are facing similar problems in the case of Poland. It is a fact that

S-Poland emerged as mainland N of the Carpathian front throughout the whole Oligocene. If there would have been any corridor or filter, it would have led directly into the Eastern Paratethys (like to the Turgai Straight), and not into the Carpathian realm of the Central Paratethys. But latest, any kind of marine connection is strongly denied. After Odrzywolska-Bienkova—Pozaryska—Martini (1978), Late Eocene was the youngest age, when fullmarine corridor opened from Poland into the Ukrainian shelfsea. In their opinion Aren's (1957) paleogeographic map incorrectly figures an Early Oligocene marine area between W-Poland and Ukraine. The cause of this error originated from the erroneous correlation of the Latdorfian stage with Early Oligocene. Sediments described earlier as Latdorfian are all coeval with the Priabonian and their stratigraphic position can be found in the Upper Eocene. The Oligocene North Sea, during its largest extension (in Late Rupelian, NP 24 nannozone), covered only the NW part of Poland and the so called Mazury-Mazowsze Barrier separated it from the Ukrainian sedimentary basin, where brackish and lacustrine sediments were deposited in marginal position. Odrzywolska—Bienkova et al. (1978) states definitely: "The existence of barrier responsible for separation of the North-European and South-Ukrainian marine basins in the Oligocene times seems undoubtful" (p. 258). Ziegler (1982) states the same: "In northern and central Poland the Oligocene and Neogene series are developed in a continental facies..." (p. 92.). This opinion appears also on his paleogeographic map.

In the knowledge of the above data, I have to modify my own paleogeographic sketch (Báldi, 1984, 1986), which has been based on Aren's map. Cavalier's (1979) paleogeographic sketch-map, as well as Nevesskaya et al.'s (1987) sketch needs also revision in this respect.

Nevertheless some reservations must be maintained. First of all: not every formation, described earlier as Latdorfian, is of Upper Eocene age. Some of them may be really of Early Oligocene (nannozones NP 21, 22), or Lower Rupelian after the new nomenclature. There are not convincing data to exclude the possibility of an Early Oligocene corridor between the North Sea and Ukraine. All we can accept, is the fact that no marine connection existed through Poland after the Early Rupelian (NP 22 nannozone). Secondly: there are full marine, Boreal mollusc-assemblages in S-Ukraine. These are hold by Vesselov (1979) for Early Oligocene in age and they are found in nannozones NP 21 and 22 after Łulyeva in Vesselov (1979). The molluscan-bearing formations are underlying the Solenoi horizon and in this sense they are pre-Paratethyan. (See also Merklin, 1974). These molluscan assemblages are not of Tethyan origin, they show very definite Boreal character. If the above data are correct, marine straight had to be existing in Earliest Oligocene toward the Boreal realm either through Poland or through the Turgai Passage. The Central Paratethys could not serve as corridor for Boreal marine benthics in Early Oligocene (see below).

The Rhine Graben opened into the Alpine fore-deep during the Oligocene. Because of the principal folding of the Jura Mts. in the Late Miocene, this connection seemed to be not so obvious earlier. The structural overprintings were analysed by Laubscher (1972), who reconstructed the original basins. This way some earlier objections, arised on tectonical ground, can be disregarded.

Nevertheless the Rhine Graben became a true, marine corridor only in Late Rupelian—Earliest Chattian times (in nannozone NP 24), when the "Rupelton" sedimented (Doebl, 1970; Sonne, 1970).

The occurrence of Boreal benthic molluscs in a rather considerable quantity in the Late Kiscellian and Early Egerian marine sediments of the Central Paratethys can be attributed to a Southward migration through the Rhine Graben (Báldi, 1973, 1986). Northward migration was more subordinated, but surely indicated by the appearance of *Miogypsina* in the Early Chattian of Doberg bei Bünde in Germany. The same *Miogypsina* species was found also in the Central Paratethys (Drooger's remark in Anderson, 1963 and Drooger, 1961).

Before Late Rupelian (NP 24), the Rhine Graben was mainly barrier for benthosfauna. The Pechelbronn Beds (NP 22), the "Fischschiefer" (of nannozone NP 23) document very unstable salinity and the anoxya of the deeper water--layers. Most probably this environment acted sometimes as filter, mainly for pelagic organisms (e.g. fishes, nannoplankton etc.).

After Early Chattian (NP 24) the sea of the Rhine Graben changed to brackish ("Cyrenen Schichten", etc.). Only euryhaline taxa could penetrate through this water. Also the Late Egerian of the Central Paratethys is in many area dominantly brackish (this is in nannozone NP 25). Boreal marine taxa could not reach directly the Paratethys from the North Sea since the beginning of nannozone NP 25 (Late Chattian, Late Egerian). All three connections can be excluded from this datum as any kind of migrational route (Turgai, Poland, Rhine Graben).

In summary, one may conclude that direct marine corridor between the North Sea and the Paratethys existend only in Late Rupelian—Early Chattian times. The place of this corridor was the Rhine Graben. Filter-like conditions, however, might be existing throughout the whole Oligocene in the Rhine Graben. Mainly pelagic organisms and some bentics with long, pelagic larval life could be able to reach the Paratethys from the North Sea, crossing the Rhine Graben Straight. The Poland and Turgai connections did not exist after nannozone NP 22, i. e. after the separation of the Paratethys. It is uninteresting for the problem of the present paper that in pre-Paratethyan (Earliest Oligocene) times the Polish and Turgai Straights emerged above the sea level or they were still covered by the North Sea, what latter case is strongly doubted and not proven.

Barriers and connections toward the Tethys

Most of the area of the inner and older tectono-stratigraphic units of the Alpine—Carpathian range was near or above the sea-level in Early Paleogene. These units were rotated, strike-slip faulted and further overthrusted still in Miocene times, therefore in paleogeographic reconstruction they have to be placed back into their original, Paleogene locations (see Báldi, 1982, 1986; Kovács—Kázmér, 1985; Balla, 1987; Mauritsch—Becke 1987; Royden—Báldi, 1988). After this reconstruction we gain place enough for a Helvetic and Flysch-Sea of considerable extent. Until Late Miocene times the internal tectonic units of the Alps and Carpathians did not barr the Flysch-Sea and other marine basins, located on their external side. The Eocene fauna is rather homogenous throughout this area, even in the S-USSR. Most probably the internal units formed an archipelago during the Eocene and Oligocene in the Carpathians, while the Alps (the Austro-Alpine unit) formed a larger island.

Progressive underplating of the northern front of the Alps led to the imbrication and deformation of the Rhenodanubian Flysch in Priabonian times and caused similar folding of the almost 150 km wide Helvetic unit in Middle to Late Oligocene times (Janoschek—Matura, 1980; Oberhauser 1980). The Early Oligocene "Fischschiefer" and the pelagic nanno-limestone ("Heller Mergerkalk") (nannozone NP 21, 22, 23) are bound mainly still to the Helvetides, though they may occur also in the inner part of the molassic basin. The piling up of northward thrusting nappes caused the elastic downwarping of the crust in the northern foreland of the Alps, widening northward the molassic fore-deep. Significantly progressed this process northward in earliest NP 24 nannozone, when the clays of the "Tonmergelstufe" — similar in many respects to the "Rupelton" — began to fill up this fore-deep depression.

It is very important from our point of view that similar underthrustings were insignificant in the Carpathians during the Paleogene. The youngest sediment of the Magura unit is Earliest Oligocene, but the Magura nappes are thrusted on top of the Silesic System, where menilites and thick turbidites of Oligocene and Earliest Miocene age are known. The Carpathian Flysch Sea survived Oligocene times without any significant disturbance (Báldi, 1986; Royden—Báldi, 1988). The main underthrustings and deformations began only after Late Eggenburgian, since the age of the Krosno Sandstone is NN 2 and NN 3 in the Eastern Carpathians.

In summary, it may be concluded that neither the Central and Eastern Alps nor the Carpathians were building any considerable obstacle against the distribution of marine benthics, including also the bathyal fauna, until Latest Eggenburgian — Ottnangian times. The scattered islands of an archipelago with deep and wide passages were not hindrance in any way for the migration of marine taxa.

The true mainland barriers of the Oligocene can be found in the southern foreland of the S-Alps and along the front of the Dinaric Alps. Large-scale, A-type subduction process occurred here in the Paleogene, which is indicated a. o. by the inner andesite arc of the Dinarides and perhaps also by the tonalites of the S-Alps. Strike-slip faults carried some fragments of this Eocene and Oligocene andesites and tonalites into Hungary. The Alpine Oligocene magmatites may have arised, however, also from the underplating process of Stable Europe in the Northern front of the Alps, too.

Doglioni—Bosellini (1987) give an elaborate, reliable reconstruction of tectonic events in the foreland of the Southern Alps. The southern ramp of this foreland was along the latitude of Milano—Verona. Sedimentation of Flysch began in this fore-deep in Late Cretaceous, Turonian times (Lombard Flysch) and lasted until Lutetian latest (Friuli Flysch). The positive flower structures of the Giudicaria sheer zone originated in Late Cretaceous times. Sea-mounts and submarine plateaus became covered by "scaglia" formations during Late Cretaceous and Eocene times.

Dinaric structural elements overprint the South Alpine structures in Friuli and they can be traced until the Periadriatic Lineament. The progressive (E ward) underthrusting in the Dinaric frontal chain took place in post-Lutetian until pre-Upper Oligocene times (Cousin, 1981).

This more accurate timing makes the understanding of the isolation of the Oligocene Paratethys much easier. Isostatic readjustments accompanying a Priabonian—Rupelian Dinaric subduction could emerge rather considerable mainland areas between the Tethys, situated along the front of the Dinarides in the west and the Paratethys located in back-arc and inter-arc position in the NE or E. The Southern Alpine front emerged above sea level still earlier, most probably towards the end of Priabonian times. South of this mainland "molasse-like", but deep marine Tethyan sediments were deposited during the Oligocene (e.g. Como-Molasse).

The S-Alpine—Dinaric—Hellenic Front had its mainland continuation in the Pontides and Taurides of Asia Minor. This barrier was dissected only at one place by the Oligocene Aegean Sea, which reached the Rhodope Massif. The overthrusting of the Balkanides in Bulgaria was also a Paleogene event, and it was accompanied by strong andesitic-rhyolitic volcanism. The direction of dip of underplating of sialic slabs was southern in the Balkanides, during an A-type subduction. Isostatic readjustments also contributed to the barrier here. (See the Tethyan Oligocene with many andesitic volcanites in the Rhodope and Paratethyan Oligocene in innermost structural unit of the Balkanides, the Srednegorie and Varna area (Burchfiel, 1980, Bontchev, 1960).

Summary

The concept of Paratethys is purely biogeographic. It is not bound to any structural unit, or to any special sedimentary environment.

The appearance of the first endemic fauna was dated at the Earliest Oligocene (Báldi, 1979, 1980, 1986). This biogeographic event clearly follows the pattern of later (Neogene) Paratethyan isolations, therefore one cannot escape the conclusion: the first occurrence of a Paratethyan bioprovince occurred as early as NP 22—23 nannozone. The Eastern Paratethys remained from this datum more or less separated, never regained the richness and diversity of Tethyan faunas. In the same time the Central Paratethys (W of Carpathians) was isolated only twice in pre-Sarmatian (pre-Late Serravallian) times. The first was the *Ergenica* event, mentioned above (about 35 m. y. ago) and the second one was the *Rzehakia* event (about 18 m. y. ago). Otherwise the Central Paratethys can be regarded for pre-Sarmatian times as a "potential bioprovince", which was connected across deep and wide corridors with the Tethys. Not only marine benthics but even tidal waves could enter the sea of the Central Paratethys for most of the Oligocene and Early Miocene times. The true mainland barriers for the Central Paratethys were formed by the southern Alpine—Dinaric—Balkanic—Pontic etc. range, along which intensive subduction and underplating processes were active in Latest Eocene—Early Oligocene times. The uplift of this range caused the Early Oligocene isolation of the Central Paratethys from the Tethys (the *Ergenica* event). The Carpathians, as barriers, could be significant only from Late—Middle Miocene times.

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