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Stratigraphic correlation of the Paratethys Oligocene and Miocene

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Oligocene-Miocene Transition
in the Northern Hemisphere

Fred Rögl

Geologisch-Paläontologische Abteilung, Naturhistorisches Museum Wien, Burgring 7, A-1010 Vienna, Austria

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The vanishing Tethys Ocean and the continental collision of Eurasia, India and Africa gave birth to the Paratethys and Mediterranean Sea. Each of these seas had an independent geological history, and the Paratethys was isolated most of the time from open ocean connections. These conditions are the reason for the development of different regional stage systems, also differing in the central and eastern parts of the Paratethys (comp. Senes 1971, 1979; Nevesskaya et al. 1984a; Steininger et al. 1985; Jones & Simmons 1996; Rögl 1996). The correlation in tab. 1 is based on the standard stratigraphic scale and biozonation of the revised Cenozoic time-scale of Berggren et al. (1995). Because of inadequate correlations and continuous changes of Blow's (1969) Neogene N-zones, Berggren et al.(1983) introduced a new M-zonation for planktonic foraminifera. Additionally the European mammal ages (Mein 1975,1990) are presented for a correlation of non-marine sedimentary basins.

Eocene-Oligocene Boundary

The Eocene-Oligocene boundary is defined by a new boundary stratotype, designated at Massignano, Italy (Premoli-Silva et al. 1988). The upper Eocene planktonic foraminiferal fauna shows extinction sequences of *Cribrohantkenina inflata, Turborotalia cocoaensis/T. cunialensis*, and the last Hantkeninidae (top of Zone P 17). No distinct calcareous nannoplankton event is observed at the boundary which falls within Zone NP 21. *Globigerinatheka index* and *Discoaster saipanensis/D. barbadiensis* disappear together in the uppermost Zone P 16 (Coccioni et al., 1988). The scarcity of late Eocene Hantkeninidae and dominating *Globigerina* faunas make it difficult to correlate this boundary outside the tropical belt. The Eocene-Oligocene boundary has been drawn tentatively at the NP 20/21 boundary in Bavaria and Austria (Martini 1981). With the appearance of *Globigerina tapuriensis/G. ampliapertura* the boundary is placed within NP 21 in Moravia (Krhovsky et al. 1991), Poland (Van Couvering et al. 1981), Hungary (Baldi et al. 1984), and Transylvania (Iva & Rusu 1982; Meszaros et al. 1989), within the sedimentary cycle of the uppermost "*Globigerina*-Marls". In the Eastern Paratethys area of Crimea and Caucasus the boundary is positioned at the FAD (first appearance datum) of *Globigerina tapuriensis* and *Ericsonia subdisticha* (NP 21) Zones (Krasheninnikov & Mouzylev 1975), but otherwise between the Beloglinian and Khadum horizons with the change to dark dysaerobic sedimentation (Voronina & Popov 1985). The radiometric age of the Eocene/Oligocene-boundary is calculated by Montanari et al. (1988) as 33.7+/-0.5 Ma.

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M. A.	EPOCH	AGE	CENTRAL PARATETHYS STAGES	EASTERN PARATETHYS STAGES	BIOZONES: Mammal Zones	BIOZONES: Planktonic Foraminifera	BIOZONES: Calcareous Nanno-plankton
5	PLIO-CENE	ZANCLEAN	DACIAN (5.6)	KIMMERIAN (5.2)	MN 14	PL1	NN13 / NN12
	5.3 Late MIOCENE	MESSINIAN	PONTIAN	PONTIAN	MN 13	M14	
10		7.1 TORTONIAN	PANNONIAN	MAEOTIAN (10.0)	MN12 / MN11 / MN 10 / MN 9	M13 (b, a)	NN11 / NN10 / NN9b
	11.0 Middle MIOCENE	SERRAVALLIAN	11.5 SARMATIAN (13.0)	SAR-MATIAN: Khersonian / Bess-arabian / Volhynian	MN 8-7	M12 / M11-M8	NN9a/8 / NN7 / NN6
15		14.8	BADENIAN	Konkian / Karaganian / Tshokrakian	MN 6-5	M7 / M6	NN5
		LANGHIAN		TARKHANIAN		M5	
	16.4 Early MIOCENE	BURDIGALIAN	KARPATIAN (17.2) / OTTNANGIAN (18.3)	KOTSAKHURIAN	MN 4	M4 / M3	NN4 / NN3
20		20.5	EGGENBURGIAN	SAKARAULIAN	MN 3	M2	NN2
		AQUITANIAN	EGERIAN	CAUCASIAN	MN 2 / MN 1	M1 (b, a)	NN1
25	23.8 OLIGOCENE	CHATTIAN	(27.5)		MP 28-30 / MP 27 - 24	P22	NP25
		28,5		ROSHNEAN (29.9)		P21 (b, a)	NP24
30		RUPELIAN	KISCELLIAN	SOLENOVIAN (32.2)	MP 23 - MP 21	P20 / P19	NP23
				PSHEKIAN		P18	NP22
35	33.7 Late EOCENE	PRIABONIAN	PRIABONIAN	BELOGLINIAN	MP 20 - MP 17	P17 / P16 / P15	NP21 / NP 19-20 / NP18

Table 1. Oligocene - Miocene correlation of Paratethys stages to the standard time scale. Absolute dating, epochs, ages, and biozonation according to Berggren et al. 1995, and Steininger et al. 1996. Correlation of Paratethys stages according to Jones & Simmons 1996, and Rögl 1994, 1996.

Early to middle Oligocene

In the Mediterranean the stage Rupelian is used for lower Oligocene which is subdivided biostratigraphically by planktonic foraminifera (P 18-P 21a) and nannoplankton (upper NP 21- middle NP 24), comp. Odin & Luterbacher (1992).

In the Paratethys a regional stage system exists. The palaeogeographic and palaeobiologic development is dominated by dysaerobic conditions. The northern European Oligocene stages (Latdorfian, Rupelian, Chattian) are used in the western Paratethys, in Bavaria and Switzerland. In the Central Paratethys a stage Kiscellian has been proposed by Baldi (1969, 1979) for the time equivalents of Kiscell Clay and Tard Clay, extending stratigraphically downwards to the Eocene/Oligocene boundary in the uppermost Buda Marls, within NP 21 (Baldi 1984). The upper boundary corresponds to the lower boundary of the Egerian (Baldi & Senes 1975) and is defined by the FAD of *Miogypsinoides complanatus* near the FAD of *Paragloborotalia opima opima*, within NP 24 (Baldi 1979). An additional stage, the Merian has been proposed by Moisescu (1975: 88) for the considered earliest development of the Paratethys. The lower boundary according to Meszaros et al. (1989) is near the boundary of NP 21/NP 22. The upper boundary corresponds to the appearance of endemic molluscs (e.g. *Janschinella, Ergenica, Cardium lipoldi*), just above the NP 22/NP 23 boundary. This stage is not used here because of its overlap with the Kiscellian (already with the first proposal in 1969), and an obvious gap to the Eocene/Oligocene boundary.

The early development of the Eastern Paratethys was formerly described as the Maikopian Series. A regional stage system is used by now, summarized by Voronina & Popov (1985): On top of the late Eocene Beloglinian stage follows the early Oligocene Pshekhian stage. It is defined by molluscs and benthic foraminifera in the time span of NP 21/NP 22. With the endemic development of Paratethys molluscs in NP 23 begins the stage Solenovian; it comprises more or less the NP 23 zone. The Roshnean stage lies within NP 24, and is correlated to the Kiscell clay in Hungary.

Late Oligocene to early Miocene

The Chattian is defined by planktonic foraminiferal zones P 21b and P 22, LAD (last appearance datum) of *Chiloguembelina cubensis* to FAD of *Paragloborotalia kugleri*, and upper NP 24 to NP 25 nannoplankton zones. The Aquitanian spans the M 1 to lower M 2 foraminiferal zones, FAD of *P. kugleri* to FAD of *Globigerinoides altiaperturus*, and the NN 1 to lower NN 2 nannozones (Berggren et al. 1995; Iaccarino 1985). In the Mediterranean Neogene the planktonic foraminiferal zones of Bizon & Bizon (1972) and Iaccarino (1985) are preferred because of the restricted occurrences of tropical globorotalias. A proposal for the Paleogene/Neogene boundary has been presented (Steininger 1994), defining the Oligocene-Miocene boundary between Chron C6Cn2r and C6Cn2n, a level bracketed by biostratigraphic markers near the FAD of *P. kugleri*.

In the Paratethys the faunal development in the late Oligocene to early Miocene is influenced by Mediterranean and Indo-Pacific connections. In both stages, Egerian in the Central and Caucasian in the Eastern Paratethys, mollusc faunas demonstrate similarities. The microfaunas of the Caucasian are distinctly less developed as those from the Central Paratethys (Nevesskaya et al. 1984a; Voronina & Popov 1985; Baldi 1973). There is a characteristic succession of larger foraminifera as *Miogypsina* and *Lepidocyclina* comparable to the Mediterranean. The Aquitanian index fossil *Paragloborotalia kugleri* is absent from all the Paratethys, correlations are based on calcareous nannofossils (Baldi & Senes 1975; Steininger et al. 1976; Rögl et al. 1979; Baldi-Beke 1984). These stages cover the upper NP 24 to NN 1/2 nannozones, where NN 1 is difficult to be determined. In the uppermost Egerian limestone facies *Miogypsinoides bantamenis/dehaarti* and *Miogypsina gunteri* occur (Papp 1975; Vanova 1975).

Upper early Miocene, Burdigalian

The Burdigalian is ranging from the middle of NN 2 to upper NN 4 nannozones, and corresponds in the Mediterranean to the *Globigerinoides altiaperturus/Catapsydrax dissimilis* to *Globigerinoides trilobus* foraminiferal zones. This long time span is subdivided in the Paratethys according to changing facies conditions.

The Eastern Paratethys stage Sakaraulian and the Central Paratethys Eggenburgian are both characterised by marine subtropical Indo-Pacific mollusc faunas. The horizon of giant pectinids is a world wide stratigraphic marker level (Addicott 1974; Steininger et al. 1976). Mainly benthic foraminiferal faunas are developed, planktonic assemblages are dominated by globigerinas. Calcareous nannoplankton determined NN2 to NN3 zones. A final appearance of *Miogypsina* (*M. intermedia*) is reported from the Austrian Molasse Basin (Papp 1960).

The correlation of the upper boundary of the Caucasian remains questionable as the following stage Kotsakhurian had a brackish water development (with endemic molluscs *Rzehakia, Limnopappia, Congeria, Melanopsis*). In the Central Paratethys marine conditions prevailed. The stage Ottnangian is defined by marine molluscs of Atlantic and boreal origin. The Ottnangian ends with regressive tendencies and in shallow estuarine areas with endemic molluscs (*Rzehakia* faunas) comparative to those of the Kotsakhurian. In the marine sediments of this stage the foraminiferal fauna is not characteristic and similar to the Eggenburgian; the nannoplankton determinations show NN 3/4. The late Burdigalian is represented in the Central Paratethys by the Karpatian stage. The west-east extending basins in the Alpine-Carpathian foredeep were followed by an intra-mountain basin configuration. Marine sedimentation occured only in a restricted area inside the Carpathian arch. Outside the Carpathian mountain chain extended dry land, and in the Eastern Paratethys continued the endemic Kotsakhurian facies. The Karpatian is dated as NN 4, and in the upper part *Globigerinoides bisphericus* appeared.

Middle Miocene

The basal middle Miocene is correlated to a world-wide warming and transgressive phase. The base of the Langhian stage is defined by the FAD of *Praeorbulina* (Cita & Premoli Silva 1968: 11). *Orbulina suturalis* appeared in the upper part of this stage (Iaccarino 1985). The Serravallian begins at the FAD of *Orbulina universa*, followed by the FAD of *Globorotalia praemenardii* and *Globigerina nepenthes* in the upper part. The nannoplankton of the Langhian and Serravallian type-sections in Piedmont spans the NN 5 to NN 8 zones (Martini 1968; Müller 1975). According to Rio & Fornaciari (1994) the FAD of *Praeorbulina* occurs some 100 m below the base of the Langhian stratotype within upper NN 4, and the base of the Serravallian is close to the LAD of *Sphenolithus heteromorphus* (beginning of NN 6).

The Carpathian foredeep and the intramountain basins of the Pannonian realm were flooded by the lower Badenian (Moravian) subtropical sea. Sediments are correlated to the Langhian by the FAD of *Praeorbulina* and *Orbulina suturalis*, and by NN 5 nannoplankton zone. In the middle Badenian (Wielician) a regression and isolation of basins created wide-spread evaporites, still in the *Orbulina suturalis* Zone.

In the Eastern Paratethys the middle Miocene Tarkhanian transgression restored the marine conditions (Nevesskaya et al. 1984b, 1987). The fauna is different from the rich Badenian assemblages. Planktonic foraminifera were predominantly small globigerinas, and dysaerobic bottom conditions occurred. The nannoplankton determinations of NN 5 (N. Mouzylev and C. Müller, pers. comm.) from the Tarkhanian stratotype enable a direct correlation with the Langhian and Badenian. Paleogeographic changes closed off the Eastern Paratethys during the Tshokrakian, creating a reduced marine environment, and further an oligohaline endemic development in the Karaganian. A direct correlation to the open oceans is missing.

Finally for a short period full marine conditions were re-established from the Transcaspian Eastern Paratethys (Nevesskaya et al. 1984b, 1987) to the Vienna Basin in the west, including the Carpathian foredeep (Dumitrica et al. 1975). This event occurred in the Konkian stage, corresponding in the Central Paratethys to the late Badenian (Kosovian) dated as NN6/7 (Rögl & Müller 1976; Andreeva-Grigorovich & Nosovsky 1976).

Beginning with the Sarmatian, in late middle Miocene the open ocean connections closed and the marine time of the Central Paratethys ended. The base of the Sarmatian is radiometrically dated as 13.6 Ma (Chumakov et al. 1992). According to nannoplankton determinations of upper Badenian (NN 6/7), and paleomagnetic dating of the base of mammal zone MN 7/8 as 12.8 Ma (Krijgsman et al. 1994), the beginning of the Sarmatian may be as young as ca 13 Ma. Mesohaline endemic faunas spread in the lower Sarmatian/Volhynian over the same area as had been covered by the Konkian/Kosovian Sea. From now on direct correlation possibilities with the open oceans are difficult. A progressive salinity reduction was more pronounced in the Central Paratethys, yielding to a confusing different use of the stage Sarmatian in the west and east of the Paratethys (for discussions see: Papp et al. 1974, 1985; Paramonova et al. 1979; Nevesskaya et al. 1984a). The Sarmatian in the Vienna Basin (sensu Suess 1866) corresponds to the Volhynian and lower Bessarabian. The upper Bessarabian and Khersonian substages of the Eastern Paratethys "Sarmatian" correlate already to the Pannonian. A distinct marker for this correlation is the FAD of the horse *Hipparion* in the upper Bessarabian in the Eastern Paratethys and Pannonian "Zone" C of the Central Paratethys (Thenius 1960; Bernor et al. 1988). Planktonic foraminifera disappeared at the base of the Sarmatian. The foraminiferal faunas consist predominantly of miliolids, elphidiids, nonionids, and some anomalinids, commonly endemic species.

Late Miocene

The Serravallian/Tortonian boundary lies within Zone M 12 (N 15 of Blow), in the *Globorotalia menardii* Zone, without a distinct foraminiferal marker (comp. Iaccarino 1985). Index fossils defining the Tortonian are *"Globorotalia" acostaensis* and in the higher part, *Globigerinoides obliquus extremus*. The base of this stage falls in the range of NN 9 (Rio & Fornaciari 1994).

In the Central Paratethys the extension of the aquatic area was drastically reduced to the inner-Carpathian basins. The Pannonian stage is characterized by an endemic oligohaline fauna of molluscs and ostracods (Papp et al. 1985). In the lowermost Pannonian the last foraminifera occur (Korecz-Laky 1985; Fuchs & Schreiber 1988). In the Eastern Paratethys which extended westwards into the Dacian basin, the endemic facies of upper Bessarabian and Khersonian continued. The lower boundary of the Tortonian is tentatively correlated to the Bessarabian/Khersonian boundary, and falls in the lowermost part of the Pannonian (Bernor et al. 1988).

A new transgression entered the Eastern Paratethys at the beginning of the Maeotian, connecting with the Aegean Sea. It is correlated by NN 10 nannoplankton to the Tortonian (Semenenko & Ljulieva 1978). The upper Maeotian returned to brackish conditions (Nevesskaya et al. 1984a).

Late Miocene, Messinian/Pontian stages

The Tortonian/Messinian boundary is positioned in marine sediments at the FAD of *Globorotalia conomiozea*. A calibration of this boundary is given by Krijgsman et al. (1994) as 7.10 Ma. The changes of the environment to salinar and fresh-water conditions within the Mediterranean Basin hinder further biostratigraphic correlations. In the Paratethys a uniform facies development is observed during the Pontian stage from the Pannonian to the Dacian and Ponto-Caspian basins. Endemic brackish water mollusc and ostracod faunas of Pannonian Basin origin spread out till to the Aegean (Gillet 1937; Kojumdgieva 1987; Rögl et al. 1991). In the Central Paratethys sedimentation ceased continuously from west to east, Pontian sediments missing in the Vienna Basin.

Miocene-Pliocene Boundary

A Miocene - Pliocene boundary stratotype has been proposed at Capo Rossello in Sicily at the base of the pelagic Trubi Marls, coinciding with the base of the Zanclean (Cita 1975). By the re-flooding of the Mediterranean full marine conditions were re-established. The base of the Pliocene is situated within the *Globorotalia margaritae* Zone of Bolli & Bermudez (1965). The boundary is astronomically calibrated to an age of 5.32 Ma (Hilgen 1991). The upper boundary of the Pontian stage in the Paratethys seems to be different to the Mediterranean Miocene/Pliocene boundary. A review of the Pliocene-Pleistocene development in the Eastern Paratethys is given by Jones & Simmons (1996).

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