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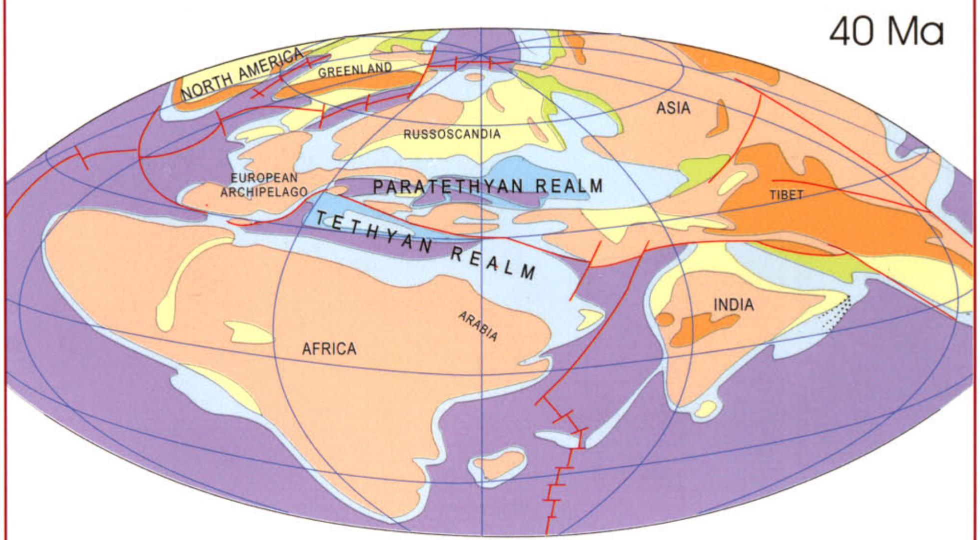

Popov, S. V., Rögl, F., Rozanov, A. Y., Steininger, F. F., Shcherba, I. G. & Kovac, M. (Eds)

Lithological-Paleogeographic maps of Paratethys
10 maps Late Eocene to Pliocene

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Popov, S.V., Rögl, F., Rozanov, A.Y., Steininger, F. F., Shcherba, I. G. & Kovac, M. (Eds)

Lithological-Paleogeographic maps of Paratethys

10 Maps Late Eocene to Pliocene

Partly sponsored by European Science Foundation

Preface

The encompassing aim of the European Science Foundation Programm "Environments and Ecosystem Dynamics of the Eurasian Neogene (EEDEN), is the detailed analysis of the response of terrestrial ecosystems to environmental change through the integration of multidisciplinary studies focussing on some selected, already fairly well-known "high-resolution" time intervals in the Neogene of the Eurasian realm. These intervals are known to (a) include major changes in the composition of terrestrial communities, (b) portray large-scale palaeogeographical reorganizations and changes in overall environmental conditions in the terrestrial realm and (c) allow the establishment of high-resolution stratigraphic correlations with data and interpretations pertaining to regional and global aspects of the coeval development of marine environments. They cover (1) the latest Miocene to Early Pliocene (HRI 1: 7 – 4 Ma ago), (2) the latest Middle Miocene to early Late Miocene (HRI 2: 12 – 8.5 Ma ago) and (3) the late Early to early Middle Miocene (HRI 3: 17 – 14 Ma ago).

The research strategy of the EEDEN – programm was realized through three corresponding, internally comprehensive, but mutually complementary and overlapping programme components. These are the terrestrial database component, the time-stratigraphic / palaeogeographic component, and the palaeobiological component.

One of the fundamental components, the time-stratigraphic / palaeogeographic component, needs to incorporate the latest dates available to reconstruct the paleogeographic / palinstastic evolution of the Tethys / Mediterranean and the Paratethys realms and to incorporate all these results in a continous sequence paleogeographic maps. Such paleogeographic / palinstastic maps as they are published here are the base for the goals of the EEDEN programm to reconstruct the Environments and Ecosystem Dynamics of the Eurasian Neogene. This new paleogeographic atlas is the continuation of earlier works within the last decade presented by Dercourt et al. 1985, 1993, 2000; Hamor (Ed.) 1988; Kovac 2002; Rögl 1998; Rögl & Steininger 1983, 1984; Senes 1960; Steininger & Rögl 1982, 1984; Steininger et al. 1985; Ziegler 1990.

We are grateful to the European Science Foundation and the Senckenbergische Naturforschende Gesellschaft, which have sponsored the publication of these paleogeographic maps within the EEDEN Programm.

Fritz F. Steininger
Frankfurt am Main, Oktober 2004

Contents

Introduction

The fundamental reorganization of the Tethyan Realm in the Cenozoic was caused by the African / Apulian / Arabian – Eurasian continent – continent collision starting during the Eocene. This resulted in the uplift and emergence of the evolving Alpine chains from the Pyrenees in the west to the Lesser Caucasus – Elburz – Kopetdagh island arcs in the east. With respect to paleogeography, the collision resulted in the break-up of the Tethyan Realm into southern (circum – Mediterranean) and northern (Paratethyan) domains, as well as in their strong fragmentation and an increase in biogeographical differentiation in the course of time. From the Oligocene onward the northern domain became subject to recurrent isolation from the Mediterranean and the world ocean.

The post-collision paleogeography and evolution of the Paratethys area from the fore-Alpine region to the Tien-Shan and Kopetdagh are portrayed by means of ten 1:7500000 maps covering the late Eocene (Priabonian), Oligocene (2 maps), Miocene (6 maps) and late Pliocene. Each map was constructed as a palinspastic map on the relevant geodynamic base (1:20.000.000). Integrated biogeographical approach was relevant for palinspastic reconstructions of the active Alpine Fold Belt, where the influence of plate tectonics was too severe and nap tectonics occur. The key information on the restoration of land bridges, marine straits and gulfs was achieved from paleobiogeographical data, since geodynamical events can hardly be reconstructed other than by the means of the areal distribution patterns of main fossil groups.

Within the last decade several paleogeographic / palinspastic reconstructions of the Tethys and Paratethys have been presented (Dercourt et al. 1985, 1993, 2000; Rögl 1998. Previous paleogeographic researches of the Paratethys area were very schematic (Senes 1961; Steininger, Rögl 1984; Rögl 1998) or concerned some parts of the Paratethys only (Vinogradov 1967–1969; Hamor (ed.) 1988; Ziegler 1990; Kovac 2002). One major weakness of these reconstructions was the incorporation of insufficient and incorrect data on the eastern Paratethys regions. Publications on paleogeography of the vast regions of the Transcaspia (Turan Plate, Kazakhstan, West Siberia), folded zones of the Greater and Lesser Caucasus, Kopetdagh, Tien-Shan and Pamir are very rare – even in Russian – and thus inaccessible for worldwide usage. More detailed summary works ("Atlas..." 1961, 1967) - were compiled 40 years ago, and they were based on a static picture of sediment / facies distribution. During the last decades abundant geophysical and borehole data on unexposed strata have been collected, and mobilistic ideas, slope-slip process analysis, and methods of palinspastic reconstructions were applied.

Compilators of the Paratethys maps are a team of paleontologists, stratigraphers, lithologist, tectonist, which had formed during the work on "Neogene paleogeographic Atlas of Central and Eastern Europe". A more detailed set of Paratethys maps were elaborated within the framework of the Peri-Tethys Programme (1996-1998, grant 25 PTP, leader S.V. Popov), but the published results (Hamor et al., 1988; Dercourt 2000) do not reflect the entire set of collected informations. I.G. Shcherba was tectonic curator for all maps. The detailed paleogeographic reconstructions of the north Black Sea area, Ciscaucasia, Volga - Don, and Mangyshlak, prepared by lithologist A.S. Stolyarov, have served as a base for the Late Eocene, Oligocene, and Early Miocene Paratethys maps. All Neogene maps in the Transcaspian part have been compiled by S.O. Khondkarian, a geologist from "Aerogeologia". Malacologists and stratigraphers from the Paleontological Institute RAS were curators of the maps: S.V. Popov (maps 1-4), I.A. Goncharova (map 5), L.B. Ilyina (maps 6, 8), N.P. Paramonova (maps 7, 10). Regional co-authors of the maps are Ju.I. Iosifova (Paleo-Don), M. Kovac (West Carpathians), A. Nagymarosy, I. Magyar (Pannonian Basin), T.V. Jakubovskaja (Belorus), T.N. Pinchuk (Cis-Caucasia), G. Popescu, A. Rusu (Transylvania, S.Carpathians), B.I. Pinkhasov (Turan area for the Paleogene maps), F. Rögl (Hellenids, fore-Alpine Basin), A.V. Zajtsev (Paleo-Donets), and A.S. Zastrozhnov (Paleo-Don). Drafts for the Black Sea depressions were adapted from D.A. Tugolesov et al. (1985, 1993). Palinspastic reconstructions for the title-pages were compiled by S.V. Popov and I.G. Shcherba in collaboration with K. Gürs (north-west Europe), M. Kovac (Alpine-Carpathian part), V.A. Krasheninnikov (North Arabia), and I.A. Goncharova (map 5). Computer versions of the Paratethys maps and reconstructions were compiled by E.S. Popova.

Our paleogeographic research was additionally supported by the Russian Foundation for Fundamental Research (grant 04-05-64459) and sponsored by the Hans Raussing Foundation.

Publishing of maps in Forschungsinstitut und Naturmuseum Senckenberg became possible through the courtesy of Prof. F.F. Steininger, technical handling was done by P. Königshof.

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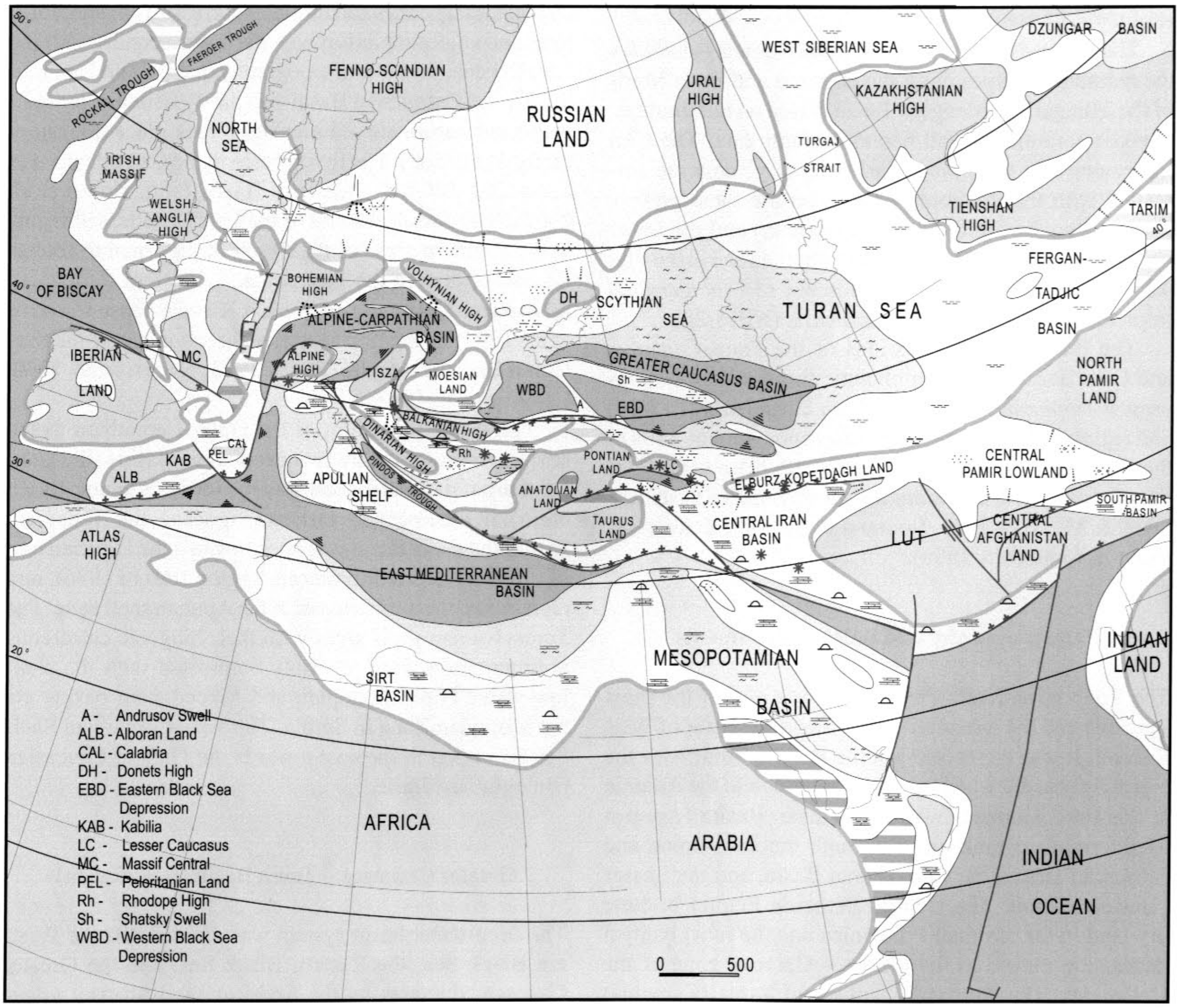
Map 1: Late Eocene
(PRIABONIAN – BELOGLINIAN) 37-34 Ma

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

Co-authors: K. Gürs, M. Kovac, V. A. Krasheninnikov, A. Nagymarosy, B. I. Pinkhasov, F. Rögl & A. Rusu



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Map 1: Late Eocene (PRIABONIAN – BELOGLINIAN)

Time slice definition and biochronology

The mapped interval includes the entire Priabonian: the *Globigerapsis semiinvoluta – Globorotalia centralis* (P15-17) planktic foraminifer zones, the *Chiasmolithus oamaruensis – Sphenolithus pseudoradians* (NP18-20) and the lower part of the *Coccolithus subdistihus* (NP21) calcareous nannoplankton zones, the *Charlesdowniella clathrata angulosa* dinocyst zone, and the *Nummulites fabiani* and *N. radiatus* zones. The corresponding numerical ages for the lower and upper limits of the interval are about 37 and 34 Ma, respectively (according to Berggren et al. 1995).

The mapped interval for the Central Paratethys includes the nummulitic limestones, the Bryozoa and Buda Marls of the Hungarian Paleogene Basin, based on nummulites, planktic foraminifer and nannoplankton data. The Cluj Limestone and the Braby Marl of Transylvania are correlated with the Priabonian, based on the same groups. Flysch deposits (up to 1500 m thickness) and the lower part of the Sheshory Marl have a Priabonian age in the Flysch Carpathians, based on the presence of *Globigerapsis tropicalis* and *Discoaster barbadiensis* (NP18-20).

The Beloglinian successions of the Trans-Caucasus and Cis-Caucasus contain planktic foraminifers *Globigerapsis tropicalis - Globoquadrina corpulenta* (P15-16) and regional *Turborotalia centralis* zones, nannofossils of the *Discoaster barbadiensis* zone (NP18-20); and dinocyst *Charlesdowniella clathrata angulosa* Zone (Krasheninnikov & Muzylev 1975, Bugrova et al. 1988, Krasheninnikov & Akhmetiev 1996).

Paleogeography and paleoenvironments

The Priabonian North Peri-Tethys was one of the most spacious and the last semi-open Paleogene basin of West Eurasia. It was connected via the Pripyat Strait with the North Sea Basin, which had no connection to the Atlantic at this time. Contacts with the Tethyan Realm (Ancient Mediterranean) took place through the Pre-Alpine and Slovenian straits, the Central Iran Basin, and the Lesser Caucasus Strait. The Central Dinaride Region became dry land in the terminal Priabonian and the relict bathyal depression moved to the Pindos – Gavrovo zone of the Hellenides. The Burgas-Kazanlik and Varna (Kamchia) gulfs, that occur side by side today, probably belonged to different basins, separated by a terrestrial barrier that extended from the Balkan Thrust Zone along the Black Sea Anatolian coast up to the Eastern Pontides and the Lesser Caucasus. Mammals of Central Asian origin (anthracothere association) could migrate along this land up to Southern Bulgaria, Slovenia and Transylvania.

The vast West Siberian Sea was an effective barrier for the Asian terrestrial vertebrate invasions. Marine connection of this sea with the Arctic Basin had been lost before Late Eocene time.

Alpine – Carpathian Basin

The deep-water part of the Paleogene Alpine-Carpathian Basin represented a system of deep troughs of the Rhenodanubian – Magura zone and the Crosno – Moldavian zone (the Dukla, Silesian, Subsilesian, Skiba, Tarcau, etc. troughs), situated to the northeast, separated in the southern areas by highs (cordilleras) that occasionally overhung as emergent islands the water. Flysch sediments of small thickness accumulating in these troughs were penetrated by thick sandy cones and turbidity currents from the cordilleras and adjacent platform. Toward the second half of the Late Eocene, the bottom topography in the central areas of the Alpine-Carpathian Basin was partly flattened by sediments and carbonate sedimentation took place (Sheshory marly deposition). The flysch basin in the Carpathians was about 200–500 km wide (e.g. Baldi 1986, Kovac et al. 2002), but towards the end of the Late Eocene, sediments in the southern areas of the flysch basin began to fold as a result of drift of the East Alpine – Western Carpathian lithosphere fragment (microplate Alcapa, sensu Csontos et al. 1992) in the northeasterly direction along the system of transform faults (Balla 1984, Nagymarosy 1990, Csontos et al. 1992).

The southern margin of the Outer Carpathian flysch sea was represented by two deep-water basins (the Central Carpathian Paleogene Basin and the Szolnok flysch basin). In the Eocene – earliest Oligocene, the Hungarian Paleogene Buda Basin was open towards the Ligurian part of the Ancient Mediterranean Region (Baldi 1986), and represented the northern part of the Apulian shelf zone. The Transylvanian shelf areas with their biogenic calcareous sedimentation were probably connected with the shallow-water Fore-Rhodopian and Macedonian basins via the Moravian Zone in Serbia. The Fore-Carpathian Shelf Sea was open in the east towards the Greater Caucasian (Beloglinian) Basin.

Greater Caucasus – Turan Basin (Beloglinian)

The deep-water basin system was divided into the Western Black Sea, the Eastern Black Sea, and the Greater Caucasus domains by the Andrusov and Shatsky ridges (Shcherba 1993). In the central parts of the Black Sea depression, up to 300–500 m of clayey sediments were deposited during the (undivided) Paleocene – Eocene, as can be inferred from seismic surveys (Tugolesov et al. 1985). Flysch sequences were accumulated in the Adzharo-Trialetic areas of the Eastern Black Sea domain (Tbilisi Flysch, up to 1000 m). The modern South Caspian

Depression is a relict of a deep, steep-walled trough of the Greater Caucasus – Kopetdagh Basin. Primary width of the trough was more then 200 km (SHCHERBA 1993, KOPP & SHCHERBA 1998).

The southern border of the Beloglinian Basin was a chain of islands, which included the Pontian, Lesser Caucasus, and Elburz-Kopetdagh uplifts, belonging to the southern part of a former Mesozoic island arc. The islands of Lesser Caucasus – South Elburz were of volcanic origin. Sandy – carbonate facies with *Nummulites* accumulated on the Transcaucasian southern shelf. The composition of the biota shows a strong Tethyan influence in the early Priabonian, then a sudden impoverishment occurred in the second half, which, together with invasions of Central Asian vertebrates, indicates the formation of a continental barrier between the Tethyan and Paratethyan realms.

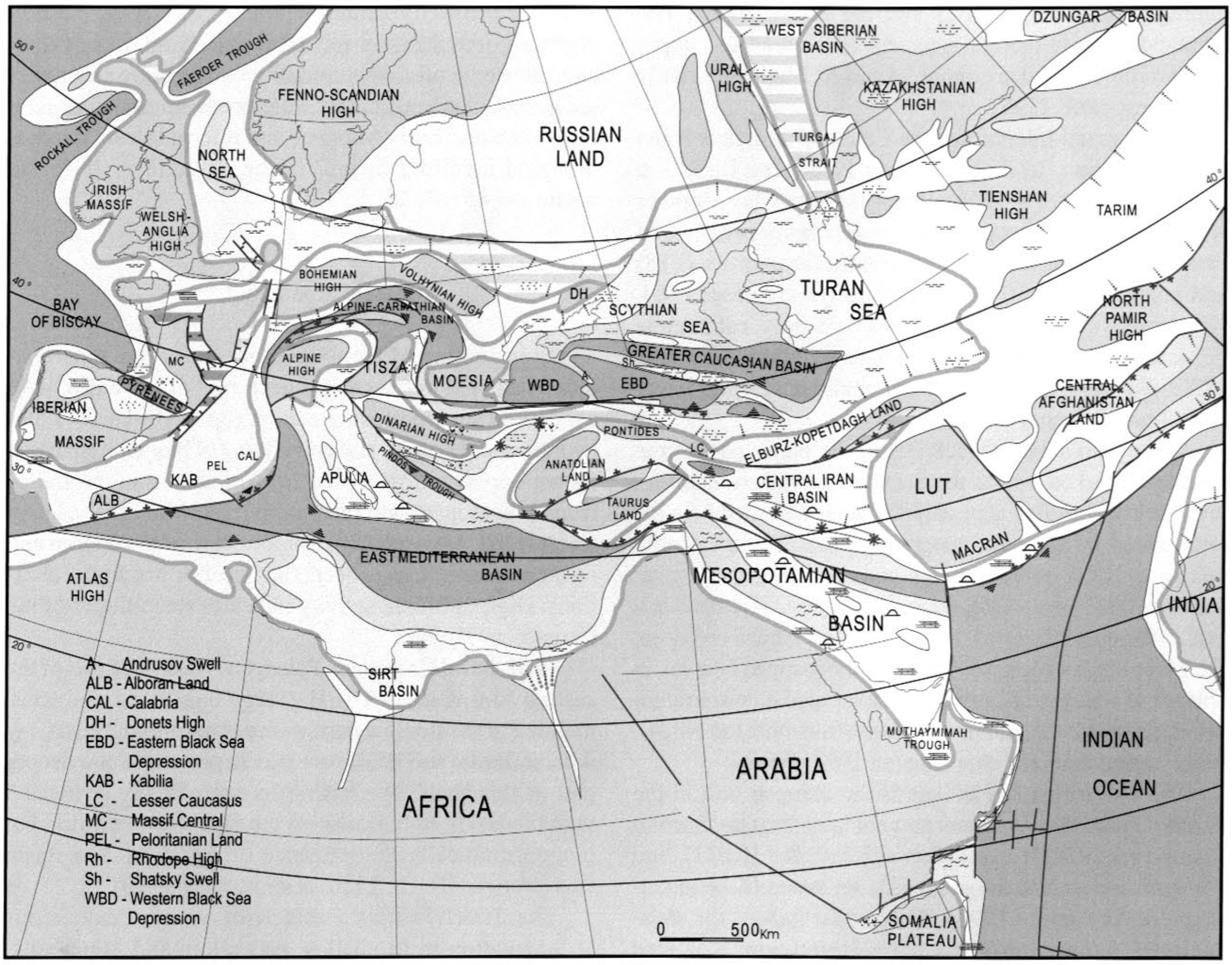
Biogenic marly sediments with rich age-diagnostic planktic fauna and flora (forams, nannofossils) were accumulated in the deep-water shelf area (up to a few hundred meters) of the Scythian Sea, the south-western parts of the Turan sea, and in the Transcaucasian area (Kura Depression). The marls belong to the *Globigerapsis tropicalis* regional zone. Clastic – mainly clayey – sediments were deposited in the shallow shelf zone of the Scythian and Turan seas which can be followed to the Turgaj, West Siberia, Fergan-Tadjic and Tarim regions. Sands had very limited distribution in the Beloglinian Basin (South Ukraine, North Aral).

The north-eastern succession yields abundant but low diversity associations of benthic foraminifers, ostracods, and mollusks, with half of the species being endemic for the Turanian Province. The Tarim Basin was an eastern gulf of the Turan Sea in the early Priabonian, but later marine sedimentation came to an end in the basin. The Elburz - Kopetdagh land was an effective southern barrier of the Turan Sea at least from the Mid Eocene.

Map 2: Early Oligocene
(Early RUPELIAN, Early KISCELLIAN – PSCHEKHIAN) 34-32

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

Co-authors: K. Gürs, M. Kovac, V. A. Krasheninnikov, A. Nagymarosy, B. I. Pinkhasov, F. Rögl & A. Rusu



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Map 2: Early Oligocene
(Early RUPELIAN,
Early KISCELLIAN – PSCHEKHIAN)

Time slice definition and biochronology

The Eocene/Oligocene boundary is taken by present authors as a boundary between the Priabonian and the Rupelian, the base of which is marked in the Paratethys by the appearance of planktic foraminifers of the *Globigerina tapuriensis* Zone (P18), within the *Coccolithus subdistichus* nannoplankton Zone (NP21) (CAVELIER & POMEROL 1986). The mapped interval – early Rupelian s.l. – is roughly equivalent to the planktic foraminiferal zone P18 and includes the upper part of the calcareous nannoplankton zone NP21 and the entire NP22. The corresponding numerical ages for the lower and upper limits of the interval are about 34 and 32 Ma, respectively (BERGGREN et al. 1995).

The mapped interval for the Central Paratethys is the early Kiscellian. In the Hungarian Paleogene Basin – a stratotypic area for the Kiscellian – the Tard Clay Member without its uppermost part ("*Cardium lipoldi* beds") is of early Rupelian age, based on planktic foraminifer (P18) and nannoplankton (NP21, 22) data (BALDI et al. 1984, NAGYMAROSY & BALDI-BEKE 1988). Sandy calcareous deposits of the Hoia and Mera beds with benthic fauna of Tethyan affinity are the facial analogues of the lower Kiscellian in Transylvania.

In the Carpathian Flysch Basin, the upper part of the Sheshory Marl as well as the Subchert and Chert members are of early Rupelian age; only the latter two members are represented on the paleogeographic map. These deposits belong to NP22 nannoplankton zone and *Wetzeliella symmetrica* (D13b) dinocyst Subzone (ANDREYEVA-GRIGOROVICH et al. 1986, KRHOVSKY et al. 1993). In the Pre-Alpine Foredeep, the lower Marine Molasse (UMM) is the mapped interval, in spite of its wider stratigraphic position based on planktic foraminifers (P17-P20), nannoplankton (from NP21 to NP24), dinocyst and mammal data (BERGER 1992, 1996).

The Pshekhian Regiostage is the mapped unit in the Eastern Paratethys. Its basal part contains the *Globigerina tapuriensis* (P18), *Coccolithus subdistichus* (NP21), and *Phthanoperidinium amoenum* (D13a) zones (KRASHENINNIKOV & AKHMETIEV 1996). The middle part of the stage includes nannoplankton of the *Helicopontosphaera reticulata* Zone (NP22) and the dinocyst *Wetzeliella symmetrica* Subzone (D13b). The upper part is characterized by dinocysts of the *Wetzeliella gochtii* Zone (D14a) and nannoplankton of the NP22-23 transitional interval.

Magnetostratigraphy provides a good control for the Pshekhian sequence (MOLOSTOVSKII & KHRAMOV 1997, KUNAEV 1990), because it belongs almost entirely to a reversed polarity zone (C12r, according to BERGGREN et al. 1995) with three normally magnetized subzones (C13n) in the earliest Pshekhian.

Paleogeography and paleoenvironments

The effects of the African – Arabian – Eurasian collision, uplifting in the Alpine Foldbelt, and eustatic sea-level drop at the terminal Eocene caused the separation of the northern basins from the Tethyan Realm. From the beginning of the Oligocene these intercontinental domains with specific paleo- and biogeography, hydrological regime, and dynamics of sedimentation were collectively named the Paratethys (LASKAREV 1924, BALDI et al. 1980) The Paratethys was subdivided into the Central European (Alpine-Carpathian) and the Euxinian-Caspian basins.

The isolation of the Paratethys along with the terminal Eocene cooling and changes to mesophilic humid climatic conditions with intensive runoff, as well as deepening of the basin bottom, led to thermohaline water stratification and to a primarily estuarine water circulation pattern, eventually resulting in recurrent episodes of stagnation and, consequently, accumulation of dysoxic to anoxic sediments. Such sediments were predominant during the Oligocene and Early Miocene and referred to as "maykopian and menilitic facies" in the Paratethys (from the beginning of NP22).

Alpine-Carpathian Basin

At the beginning of the Oligocene, specific marine conditions existed in the central deep part of the basin, with condensed suboxic sedimentation (up to 10–15 m). Later hydrothermal activity and embedding of biogenic elements (phosphorus, nitrogen) led to explosive diatom and/or nannoplankton growth (near the NP22/23 boundary, lower Chert level). Monospecific composition of the diatom and nannoplankton flora reflects the onset of brackish conditions. High turbiditic activity indicates steep slopes of the Carpathian Trough.

The Central Carpathian Paleogene Basin was part of the eastern Alcapa shelf. The Harshegy Sandstone was accumulated in the shallow part, whereas the anoxic Tard Clay with andesitic tuff sublayers was deposited in the deeper part of this shelf. The basin was episodically connected with the North Italy Basin via the Slovenian corridor, but biogeographically the influence of the North Sea Basin was stronger (BALDI 1986, NAGYMAROSY 1990).

The Transylvanian Basin with sandy – calcareous sedimentation in its shallow part (Hoia and Mera beds) was part of the Apuseni Shelf. Biogeographical data indicate its connection with the Fore-Rhodopian Basin of the Tethyan Realm.

Shallow-water sandy-clayey sediments of the narrow northern shelf were preserved in the Pre-Alpine Foredeep and are known in turbidite composition only in the Carpathian Flysch Basin.

Eastern Paratethys

After the terminal Eocene regression, a new transgression took place at the beginning of the Oligocene. According to biogeographical data, the main connection of the basin with the open sea was in the west, towards the North Sea Basin.

Dysoxic clayey facies, which reflects a hydrogen sulfide poisoning, was very typical for the deep part of the Maykopian Basin during Oligocene – Early Miocene. These conditions led to the accumulation of dissolved manganese in the sulphidic zone and its subsequent precipitation on the shelf. Varna (NE Bulgaria), Nikopol (South Ukraine), Chiatura (West Georgia), and Mangyshlak are localities with commercial amounts of manganese sedimentary ores (second part of NP22, D13b *Wetzeliella simmetrica* Subzone).

The northern part of the Eastern (Maykopian) Paratethys was occupied by a spacious shallow shelf zone with coarser clastic sedimentation. It was separated from the deep Black Sea – Great Caucasus - South Caspian depressions by a system of islands and shallows stretching from the Ukrainian Shield to the highs of Mangyshlak and North Ustjurt. The paleobotanical and paleozoological evidence shows a gradual change from a xerophytic subtropical climate to a temperate mesophilic one.

The Western Great Caucasus (Lagonaki), Dzirul and (?) Crimea Islands occupied isolated positions in the middle part of the Maykopian basin. The Pontides, Lesser Caucasus, and Elburz were an uplifting system, which separated the Eastern Paratethys from the Tethyan Realm. The narrow southern shelf extended along this land.

The next period of the early Oligocene Paratethys history (NP23, D14a *Wetzeliella gochtii* subzone) was connected to the first separation of the basin from the world ocean and a consequent reduction of salinity.

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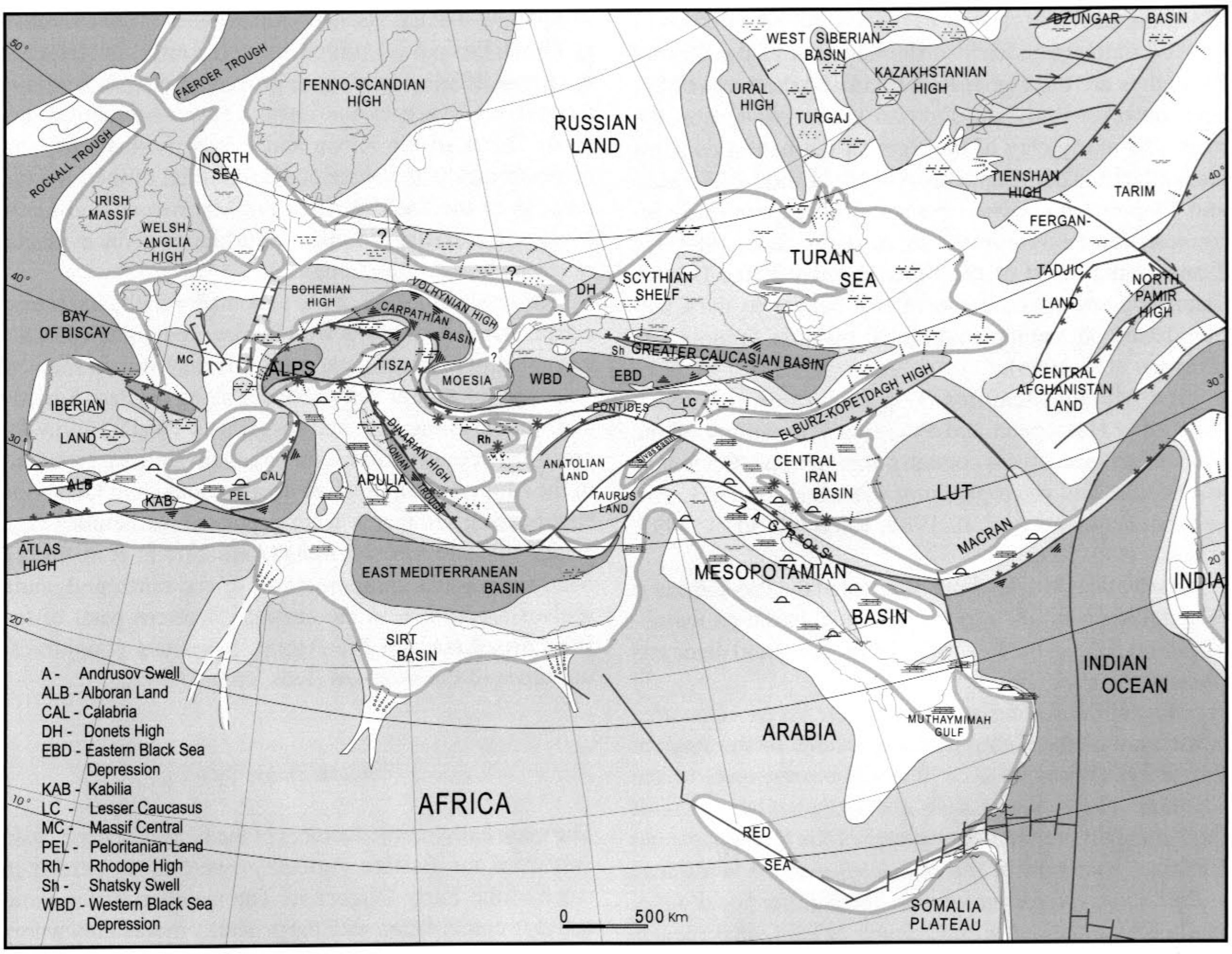
Map 3: Late Oligocene
(CHATTIAN – EGERIAN – KALMYKIAN) 29-24 Ma

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

Co-authors: K. Gürs, M. Kovac, V. A. Krasheninnikov, A. Nagymarosy, B. I. Pinkhasov, F. Rögl & A. Rusu



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Map 3: Late Oligocene (CHATTIAN – EGERIAN – KALMYKIAN)

Time slice definition and biochronology

The mapped interval includes the entire Chattian and covers a time-window from about 30 to 24 Ma. In fully oceanic successions the Chattian corresponds to the *Globorotalia opima opima* (P21b) and *Globigerina ciperoensis* (P22) zones. The Chattian stratotype area (NW Germany) is characterized by the upper part of the nannoplankton zone NP24 and zone NP25, planktic foraminifer zone P22 and presence of *Lepidocyclina morgani, Miogypsina septemtrionalis*, dinocysts belong to the upper part of the *Chiropteridium partispinatum* zone, or zones D14b, D15 (Pomerol 1981).

The time-equivalents of the Chattian in the Central Paratethys are the Upper Kiscellian and the Lower Egerian; however, only the Egerian is represented on the map. The marly clay of the Egerian Formation contains nannoplankton of the upper part of NP24 and NP25 zones, and *Globorotalia opima opima* and *Miogypsina septemtrionalis* forams (Nagymarosy & Baldi-Beke 1988). In Transylvania, most of the Vima Formation, the Buzach Sandstone and its time-equivalents belong to the Chattian, based on nannoplankton and planktic foraminifers (Popescu et al. 1996).

The Middle Menilites (Lopjanica), lower Crosno, Zdanice – Hustopece and Pucioasa Formations of the Carpathian successions contain a similar upper Oligocene microfauna and phytoplankton (Cicha et al. 1971, Andreeva-Grigorovich et al. 1986, Krhovsky et al. 1993, Popescu et al. 1996).

The Middle Maykopian Subseries of the Pre-Caucasus is correlated with the upper Oligocene, based on nannoplankton (NP24, NP25 – data of J.Krhovsky) and dinocysts (Akhmetiev et al. 1995).

Most of the Kalmykian Suite of the Volga - Don area is the type of the Kalmykian Regiostage of the Eastern Paratethys (Popov et al. 1993) and corresponds to the Chattian. The Karatomakian and Baigubekian suites of the Turan part are time-equivalents of the Kalmykian and Chattian, based on of the *Spiroplectammina terekensis – Elphidium onerosum* benthic foraminifer local zone, mollusk associations with *Chlamys bifida* (zonal species of the Chattian A), and *Cerastoderma prigorovskii*, and *Chiropteridium partispinatum* dinocyst Zone.

Paleogeography and paleoenvironments

After the Solenovian episode, when the entire Paratethys was characterised by brackish salinities and endemic biota, connections with the world ocean opened again and a marine regime was re-established in the late Oligocene. Biogeographical data indicate that marine connections existed towards the North Sea Basin. According to Berger (1996) and Sissingh (1997) the Western Paratethys had a temporal marine connection via the Rhine Graben System, although from other data the graben only had brackish conditions during that time. The Central Paratethys was connected with the Mediterranean via the Slovenian corridor. The position of the marine passage to the Eastern Paratethys, however, cannot be ascertained, because the marine late Oligocene deposits are not easy to determine in the Dnieper-Donets Depression and unknown in the Pripyat and the North Poland areas, where the early Oligocene strait existed.

Alpine-Carpathian Basin

The part west of the Silesian - Audia zones of the Carpathian Flysch Basin was uplifted and partly emergent (Beer & Shcherba 1984). Uplifting is proved by coarse-rhythmic terrigenous flysch of the lower Crosno Formation, the sandy facies of the Kliwa and Fusaru Formations, and olistostromes with coarse clastic material of the foreland area, as in the Eastern Alps, the Marmarosh and Getic Mesozoic massifs. Presence of turbidites gives evidence of steep slopes of the troughs.

Regression took place on the southern shelf, and coarse clastic brackish deposits with lignite predominated in the western part of the Hungarian and Transylvanian shelves. Andesite volcanic activity occurred along the Peri-Adriatic and Middle Hungarian sutures (Balla 1984), and in depressions of eastern Serbia and southern Bulgaria, whereas in the Morava – Shumadian area lagoonal and lacustrine coal-bearing sediments were deposited, sometimes with acidic volcanic intercalations (Andjelkovic et al. 1991). Sandy clays and conglomerates of the north and south shelves are known in the central – western parts of the Pre-Carpathian and Pre-Alpine foredeeps (Lopjanica; turbidites of Puchkirchen Beds, up to 1000 m).

Eastern Paratethys

The main bathymetric features of the late Oligocene basin system of the Eastern Paratethys were fairly similar to those of the Early Oligocene. The isolation of the Paratethys in combination with the generally moderately warm, humid climatic conditions and intensive runoff resulted in an estuarine water circulation pattern and recurrent episodes of stagnancy of parts of the water column, and, consequently, in the accumulation of anoxic sediments. Anoxic clayey sedimentation was predominant in the Crimea-Caucasian-Kopetdagh deep-water environments ("maykopian facies").

The south shelf area was reduced in comparison with the early Oligocene one. Sea regressed from the Adzharo-Trialetic region (Akhaltsikhe) and Araks Depression. The coarse terrigenous littoral facies are traced along the northern slope of the Lesser Caucasus. Clayey deposition with episodic intercalations of anoxic facies and sandy tubidites continued to accumulate in the deeper shelf zone.

The Russian landmass and the Ural and Kazakhstan Highs to the north, and the Lesser Caucasus – Elburz – Kopetdagh uplifts to the south were the main sources of clastic material in the Eastern Paratethys.

The northern and especially the eastern shelves experienced transgression after the late Solenovian regressive phase. Clayey sedimentation without age-diagnostic fossils and benthic remains predominated in the outer shelf area. Specific planktic dinocyst associations testify anoxic influences even into the photic zone. The Terek-Mangyshlak and Indol-Kuban deepest shelf depressions were filled up by clastic material, showing clinoformic geometry, and attaining up to 1000-2000 m thickness, as can be inferred from seismic surveys (KUNIN et al. 1989). Condensed deposition with abundant fish remains was typical for the northern border of the Terek-Mangyshlak Depression. Exploitable concentrations of uranium and rare-earth elements were associated with these facies in the Volga-Don and Mangyshlak districts.

Sandy-silty accumulation with scanty euryhaline benthic fauna prevailed in the shallow zone. The *Cerastoderma prigorovskii – Lenticorbula helmerseni* mollusk association and the *Elphidium onerosum – Cibicides ornatus* benthic foraminifer assemblage were very characteristic for the entire northern and eastern shelf zone in the late Kalmykian time.

The Turanian domain was an area of mainly shallow shelf accumulation. Movements along the Amudarja and Western Aral regional fault systems controlled the facies distribution and thickness of the marine sequences. Reddish sandy – silty successions with evaporites were deposited in the Kyzylkum bay and in the eastern part of the Fore-Kopetdagh bay. The Karatau, Tien-Shan, and Kopetdagh were the main positive topographic features of the eastern border.

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Map 4: Early Miocene
(BURDIGALIAN – EGGENBURGIAN – SAKARAULIAN) 20,5-19 Ma

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

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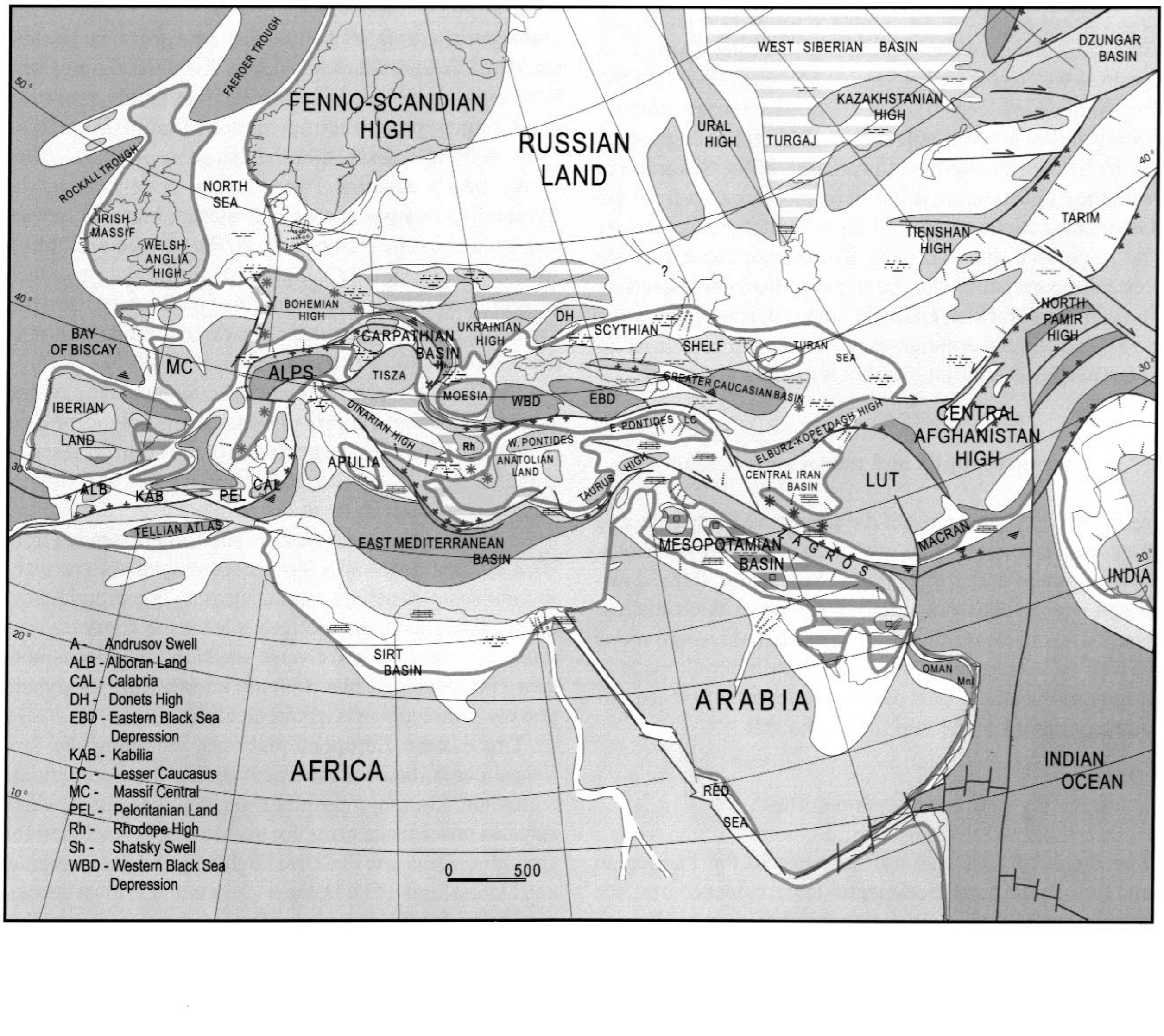

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Map 4: Early Miocene (BURDIGALIAN – EGGENBURGIAN – SAKARAULIAN)

Time slice definition and biochronology

The mapped interval covers a time-window from about 20.5 to 19.0 Ma and correlates with the early Burdigalian. It is characterized by nannoplankton associations of the upper part of NN2 and the lower part of NN3. These zones can be recognized in the warm-water, fully marine sequences of the Central Paratethys, which allows correlation of the Early Burdigalian with the Eggenburgian regional stage (Steininger et al. 1985, Nagymarosy & Müller 1988). The Boudky and Poljanica formations and the lower part of the Upper Crosno Formation are time-equivalents of the Eggenburgian in the Carpathian Basin as well as the Upper Marine Molasse (OMM) of the Pre-Alpine Foredeep (Berger 1992). More scanty paleontological data are available for the Sakaraulian regiostage of the Eastern Paratethys. Correlation of the Sakaraulian with the Eggenburgian is based on mollusk data from the Georgian sections of the mid-Kura Stratotypic region. At the same time, the overlying Kozahurian sequences are certainly correlated with the upper Ottnangian, based on the common brackish endemic fauna (Popov & Voronina 1983), so the Sakaraulian may correspond to a broader interval (Eggenburgian – early Ottnangian).

Paleogeography and paleoenvironments

As in the Oligocene, most of the successive Early Miocene deep-water environments were characterized by clayey sedimentation under dysoxic to anoxic conditions, associated with an estuarine circulation system. Rich shallow benthic warm-water fauna, diverse planktic associations as well as floristic data from the shallow Inner-Carpathian basins and southern part of Transcaucasia reflect the climatic optimum of the mid Early Miocene.

Alpine-Carpathian Basin

The Eggenburgian was transgressive in the Pannonian and Pre-Alpine parts. Sedimentological evidence from the mainly sandy shallow-water deposits as well as the rich fossil associations testify fully marine conditions, and high tidal activity (Sztano 1994) proves a free connection to the Mediterranean via the Pre-Alpine passage.

Silty-clayey and turbiditic sequences were accumulated in the deepest part of the Outer Carpathian "residual flysch trough" (Crosno and Silesian zones). At the same time, most of the Carpathian Basin became an area of carbonate clastic deposition. These facies successions may reflect not only shallowing, but warming and development of an anti-estuarine (Mediterranean) circulation system as well (Krhovsky et al. 1993).

Eastern Paratethys

After a widespread, short-term transgression at the beginning of the Miocene, regressive tendencies became predominant in the domains of the Eastern Paratethys. This is especially evident in the northern parts of the Eastern Paratethys, i.e., in the southern Ukrainian area and in the Volga – Don, Pre-Caspian, Ustjurt and Aral regions.

Clays, rich in organic matter and pyrite, continued to accumulate in the outer shelf areas and in depressions during the Early Miocene (including the Sakaraulian). The supposedly time-equivalent, rich and diversified shallow-water mollusk associations from the southern part of the Transcaucasus area, as well as the time-equivalent benthic foraminifers and fish associations from the Crimea and Pre-Caucasus include Indo-Pacific immigrants, presently inhabiting tropical–subtropical seas (mollusks such as *Fragum, Plagiocardium,* or the fish genus *Alepes*). Salinity was nearly euhaline. Palynological evidence from the Sakaraulian stratotype area indicates an increase in subtropical and exotic elements (L.A. Panova, pers. comm.). Arid floral elements (e.g. *Ephedra*) from deposits which accumulated at the eastern margin of the Eastern Paratethyan realm, indicate seasonal climatic conditions including dry summers (Akhmetiev in Popov et al. 1993).

The Early Miocene bathymetric contours of the central area of the Eastern Paratethys were like the Oligocene ones (Shcherba 1993); the deepest parts of the basin correspond to the Western Black Sea, Eastern Black Sea and Greater Caucasus – South Caspian depressions.

A narrow, elongated southern shelf zone extended from Western Georgia towards Eastern Azerbaijan. As a result of continuing uplift of the Lesser Caucasus, Talysh and Elburz chains, sandy sedimentation prevailed in the Transcaucasus southern shelf. Rich and diverse benthic associations (more than 100 species of bivalves) are known from sandy and gravely sediments of Central Georgia.

The Eastern European platform, including the Pre-Caspian area, became emergent during the interregional regression. The major positive topographic features, which acted as provenance areas for clastic supply, included the Ural Mountains, the Pre-Ural Highland, and the Ukrainian and Donets lands. The Dnieper-Donets and Pripyat depressions were transformed into alluvial plains with lakes.

The Scythian Plate continued to represent the northern shelf of the Eastern Paratethys. Its northern, shallow-water areas were subject to sand and silt deposition. The Terek-Mangyshlak Depression developed from a very deep shelf basin with condensed sedimentation into a region beyond shallow-water shelf deposition. Outer shelf depositional environments existed at the southern part of the Scythian Plate. The deep shelf conditions as expressed in the deposition of dysoxic clays prevailed in the northern Crimea area and in the Fore-Caucasian basin. The Indol-Kuban Depression represented the deepest part of the northern shelf areas of the Eastern Paratethys, where "Upper Maykopian" (i.e., undivided lower Miocene) sequences reach thicknesses of up to 1000–1500 meters. Coeval uplift of the Central Caucasus resulted in an increased supply of clastic material into the Fore-Caucasian Basin (Laba sands, siltstones of the Olginskaja Suite).

In the northern shelf areas overall sedimentary changes occurred from accumulation of muds towards deposition of sands and silts during the Sakaraulian. Concurrently, the oxygenation of bottom water improved and, consequently, benthic communities diversified and inhabited newly established biotopes.

Shallow seas occupied the northern (Ustjurtian and Pre-Aralian) parts of the Turan Plate during the beginning and the later part (Kozahurian or "Rzehakia time") of the Early Miocene. In between, i. e., during the Sakaraulian, continental environments prevailed in these areas. In contrast, marine, sandy to clayey Sakaraulian deposits accumulated in the South Mangyshlak, Karakum and Fore-Kopetdagh domains. In the South Mangyshlak Basin a change from shallow-water into deep-water shelf environments occurred (Stolyarov data in Popov & Stolyarov 1996). The Karakum – Fore-Kopetdagh Gulf was separated from the main basin systems of the Eastern Paratethys by the large Tuarkyr Island. Farther to the east, shallow-water clastics accumulated in the Fore-Kopetdagh Gulf. In this basin the middle part of the Aktepe Sands were dated as Sakaraulian (Voronina et al. 1993). Source area of the sands was the Kopetdagh Land. Only the northwestern part of the Kopetdagh area was submerged. It was a deep shelfal depression where anoxic clayey deposition continued.

The lowlands and continental depressions of southern West Siberia, Turgaj, South Kazakhstan, Tien Shan and Tadjik regions together constituted a paleogeographic complex comprising large fresh-water lakes ("Great Lake Time"), in which mostly clayey, reddish sediments accumulated.

Map 5: Early Middle Miocene
(LANGHIAN, Early BADENIAN, CHOKRAKIAN) 16-15 Ma

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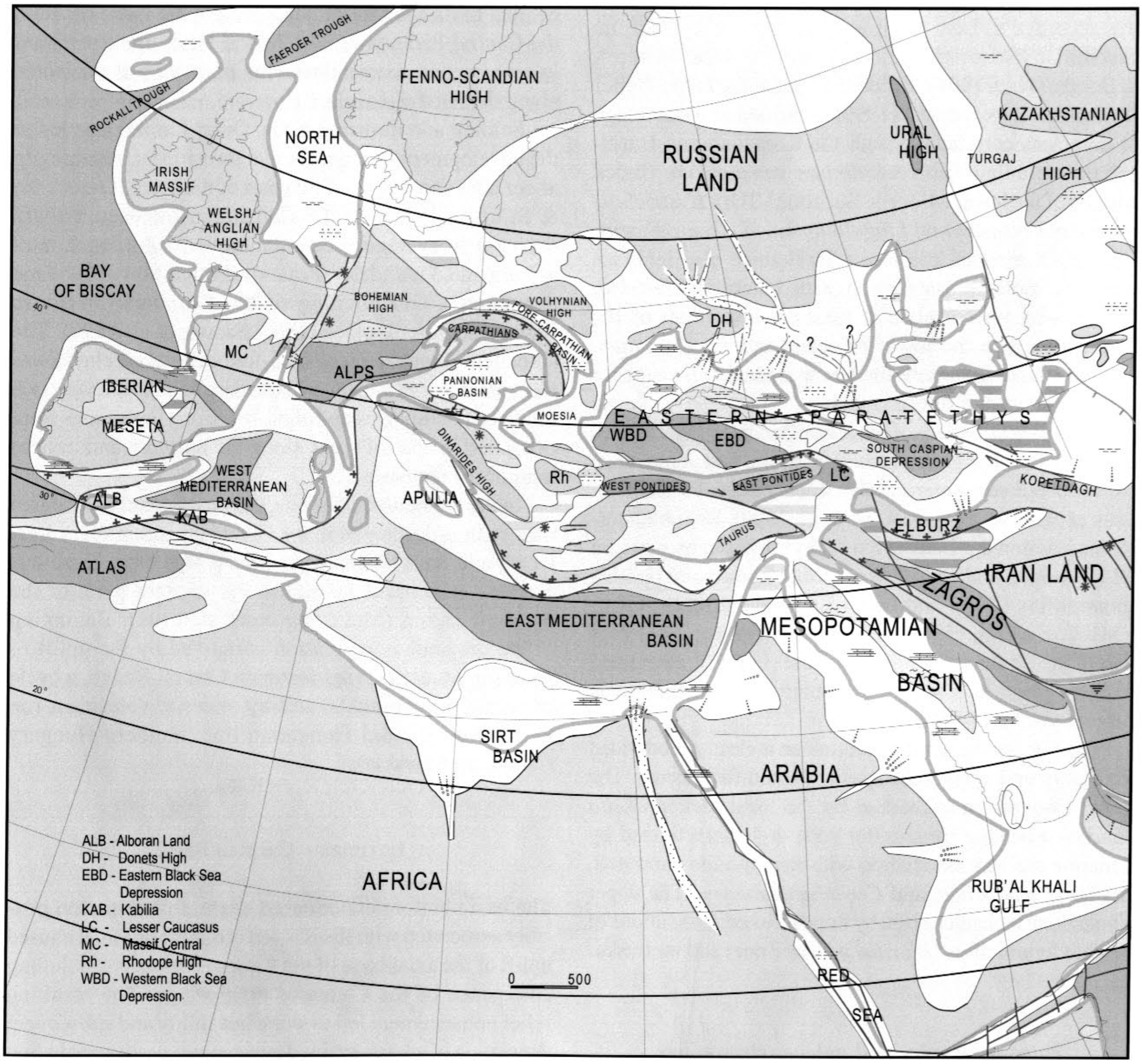

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Map 5: Early Middle Miocene (LANGHIAN, Early BADENIAN, CHOKRAKIAN)

Time slice definition and biochronology

The mapped interval includes the Early Badenian of the Central Paratethys and the Chokrakian of the Euxinian – Caspian Basin; they are roughly correlated with the Langhian (see stratigraphic scheme). Alternatively, the Early Badenian was proposed to correlate mainly with the Tarkhanian based on NN5 nannoplankton identified in the lower Badenian as well as in the Tarkhanian (RÖGL 1998, ANDREYEVA- GRIGOROVICH & SAVITSKAYA 2000). However, *Helicosphaera ampliaperta*, a zonal species of NN4, was recorded in both the middle and upper units of the Tarkhanian (NOSOVSKY & BOGDANOVICH 1984, KONENKOVA & BOGDANOVICH 1994). In addition, from the lower Upper Tarkhanian ZAPOROZHETS (1999) identified an assemblage of dinocysts correlatable with the Karpatian and Burdigalian, including *Tuberculodinium vancampoae* (index species of the lower Miocene Subzone VII b), *Hystrichosphaeropsis obscura* and *Lingulodinium machaerophorus*. Like the Karpatian, the lower Tarkhanian also includes a marine mollusk association with inherited *Rzehakia*. That is why we correlate at least the lower half of the Tarkhanian with the lower Miocene and the Karpatian, and the Chokrakian with the lower Badenian (except for the lowermost part of the latter).

The lower boundary of the lower Badenian (Moravian), like that of the Langhian, is marked by the first appearance of *Praeorbulina glomerosa*, dated at about 16,4 Ma (BERGGREN et al. 1995, MEULENKAMP et al. 2000). Regional correlation within the Central Paratethys is based on planktic (*P. glomerosa* and *Orbulina suturalis* Zones) and benthic foraminifers (lower and upper Lagenid subzones: GRILL 1941, CICHA et al. 1998). In the Alpine foredeep, the lower part of the Upper Freshwater Molasse (OSM) is correlated with the lower Karpatian – Badenian based on mammals (uppermost MN4-MN5).

The Eastern Paratethys Chokrakian is clearly subdivided into lower and upper substages (Zuk and Bryk beds). The lower Chokrakian is marked by the local *Tschokrakella caucasica* benthic foraminifer zone and characterized by a marine mollusk association with *Aequipecten varnensis*, *Ervilia praepodolica*, and *Cerithium cattleyae*. The upper Chokrakian is characterized by impoverished associations of benthic foraminifers (*Florilus parvus* Zone) and mollusks.

Paleogeography and paleoenvironments

After the late Burdigalian paleogeographic and paleoenvironmental reorganization, oceanization of the Western Mediterranean basin continued; the Sardo-Corsican block rotated counterclockwise about 45 degrees (MEULENKAMP et al. 2000). The Aegean area experienced large-scale south-westward directed thrusting. The Arabian platform experienced major transgression during first part of the Mid Miocene. The northern part of the Gulf of Suez – Red Sea rift system was open but an emerged isthmus probably still separated it from the basins of the southern rift system.

Alpine – Carpathian – Pannonian domains

In the terminal Burdigalian, the northvergent thrusting of the Eastern Alps ended. Marine deposition in the Fore-Alpine molasse basin persisted only near the Rhone graben (Valence Basin). Uplift of the southern margin of the Bohemian massif led to its paleogeographic isolation from the Central Paratethys. The Alpine thrust front persisted in activity, and coarse clastic fan material was deposited along the Alpine margin.

Folding and thrusting in the Outer Carpathians led to the development of a new active thrust front, resulting in about 60% shortening of this part of the basin (OSZCZYPKO & SLACZKA 1985). In the Carpathian foredeep a sharp decrease in average accumulation and subsidence rates accompanied with lateral eastward migration of foreland depocentres and opening of the Pannonian back-arc basin system took place (MEULENKAMP et al. 1996). The so-called "Tegel" facies (sand-free calcareous clays) was most abundant in the lower Badenian. Sands with very rich mollusk assemblages and algal-bryozoan limestones were deposited in coastal areas along the northern and eastern margins of the basin.

In the Pannonian domains, the deepest early Badenian depocentres developed in the Great Hungarian Plain area, Drava and Sava basins (transitional area from Tisza microplate to Dinarides), and in the western parts of the Apuseni region (MEULENKAMP et al. 1996). Beginning of the orogenic compression is marked by the uplift of Apuseni, Mecsek, Transdanubian Central Range, a cycle of paralic brown coals, and by andesite volcanism (up to 3000 m, Central Hungarian line, northern Hungary – southern Slovakia).

Euxinian – Caspian Basin

The basin bottom experienced sharp differentiation possibly associated with the Styrian orogenic phase. It caused uplift of the axial zone of the Eastern Paratethys including emergence of the Caucasus archipelago. The resulting relief enhancement led to slope instability and subsequent deposition of coarse-grained terrigenous clastics, including turbidites (SHCHERBA 1993).

The early Chokrakian sequences are transgressive, particularly in the northern and eastern parts of the basin system. Irrespective of the regional transgression, connections with the world ocean became more restricted. Early Chokrakian exchange of water masses with the Mediterranean realm and Mesopotamian Basin probably occurred via the mid-Araksian corridor and through basins in Iran, eastern Turkey and NW Syria (GONCHAROVA 1989, GONCHAROVA & SHCHERBA 1997, GONCHAROVA et al. 2001, 2002). The prevalence of marine environments with fluctuating salinities changed in later Chokrakian time into a semi-marine (<15‰) regime with impoverished euryhaline faunas. In mid-Chokrakian time an unstable land bridge intermittently connected the Greater Caucasus island with Asia Minor and Africa, thus permitting immigration of African mammals (*Orycteropus, Kubanochoerus*) into the Euxinian – Caspian Basin (ZHEGALLO in GONCHAROVA & SHCHERBA 1997). The Chokrakian climate was probably subtropical with warm-water mollusks (GONCHAROVA 1989), mesophylic subtropical floral elements and, locally, mangrove-type vegetation, all indicative of the "second Miocene climatic optimum" (AKHMETIEV 1993) persisting from the Tarkhanian into the Chokrakian. Relatively arid conditions existed in the Trancaspian domain, as evidenced by the vast distribution of evaporites and reddish-colored clastics.

The deepest parts of the northern shelf of the Euxinian-Caspian Basin were the West Kuban and the southern part of Terek-Caspian depressions. In the Kobystan – South Caspian depression, deep water environments were retained only east of the Lazarevskoe-Kobystan trough. The southern shelf showed deep water deposits in the Iori-Kura depression. Algal-bryozoan reefs developed on the top of escarpments. In the Transcaspian domain, in addition to the North Ustjurt and Fore-Kopetdagh depressions of pre-Chokrakian age, the North-Caspian, South Mangyshlak and a few depressions in the South Aral – Kopetdagh region were formed anew.

The Russian Highland and the Ural High were the main positive topographic features in the Chokrakian. The Russian Highland was drained by the Paleo-Don, whereas the Paleo-Donets drained the Dnieper-Donets Lowland.

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Map 6: Mid Middle Miocene
(Middle SERRAVALLIAN, Late BADENIAN, KONKIAN) 14-13 Ma

Compiled by: L. B. ILYINA, I. G. SHCHERBA, S. O. KHONDKARIAN & I. A. GONCHAROVA

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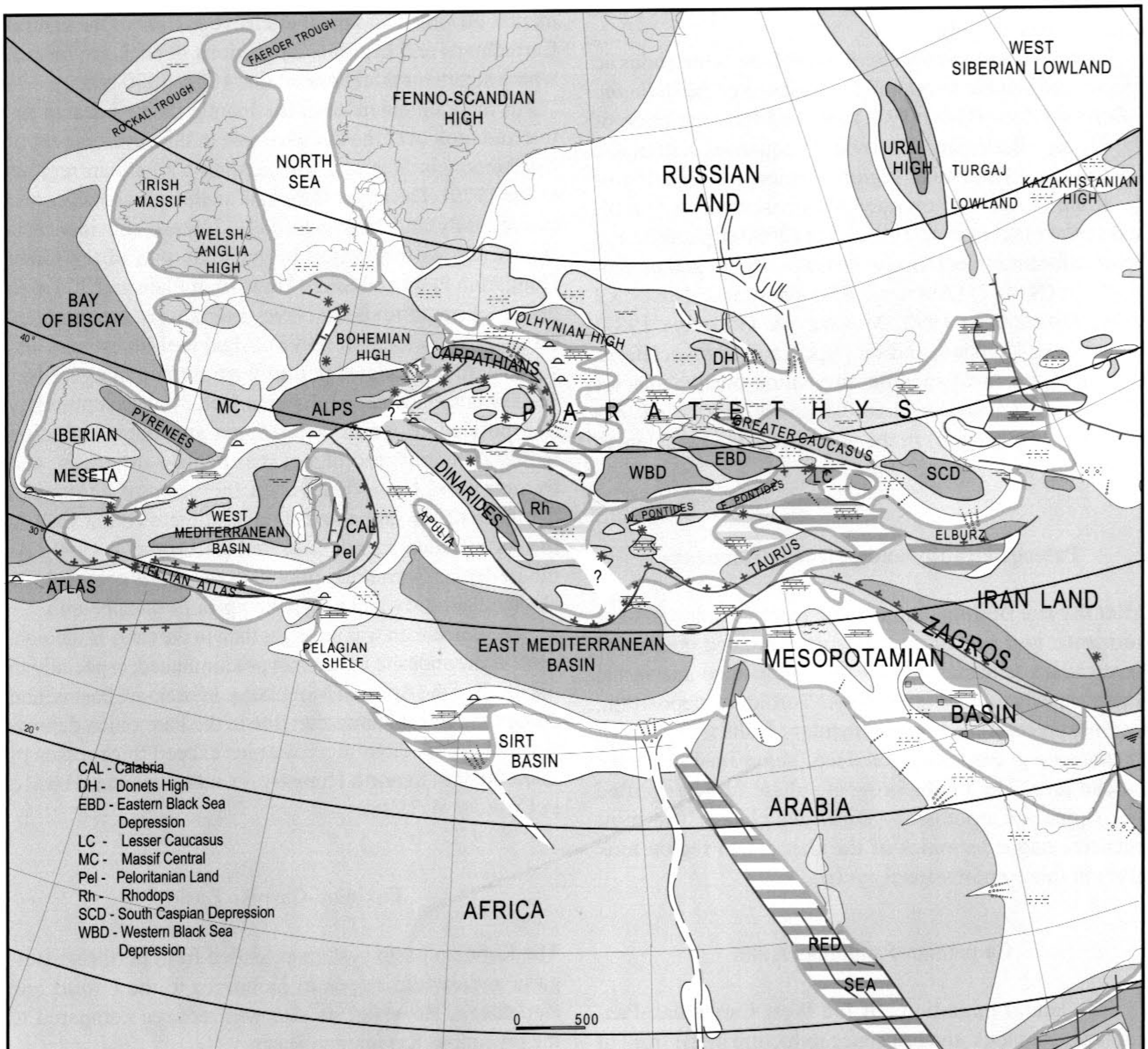

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Map 6: Mid Middle Miocene (Middle SERRAVALLIAN, Late BADENIAN, KONKIAN)

Time slice definition and biochronology

The mapped interval for the Paratethys includes the late Badenian substage in the Central Paratethys and the Konkian regiostage in the Euxinian-Caspian basin system. These intervals are roughly equivalent based on a common upper boundary with the Sarmatian regiostage, nannoplankton of NN6-7 zones (ANDREEVA-GRIGOROVICH & NOSOVSKY 1976, RÖGL & MÜLLER 1976), and similar macrofossil associations and evaporite distribution in the underlying middle Badenian (Wielician) and Karaganian deposits, respectively.

The local *Velapertina indigena* Zone with endemic species and benthic foraminifer association of the *Bulimina – Bolivina* Zone (GRILL 1941) are used for correlation of the Upper Badenian (Kosovian) sequences within the Carpathian – Pannonian region. Regional correlation of the Konkian is based on polyhaline associations of mollusks (NEVESSKAYA et al. 1986, ILYINA 2000a), planktic and benthic foraminifers (KRASHENINNIKOV 1959), and nannoplankton (NN6-7) (ANDREEVA-GRIGOROVICH & NOSOVSKY 1976, MINASCHVILI 1992, MUZYLEV & GOLOVINA 1987) in the lower Konkian, and on impoverished associations with domination of specific euryhaline bivalve species (*Parvivenus konkensis, Acanthocardia andrussovi, Ervilia pusilla trigonula*) in the upper Konkian (Veselanian Beds).

Paleogeography and paleoenvironments

After the late Burdigalian tectonic reorganization intense horizontal and vertical movements continued during the Serravallian, especially in the Appenine zone and in the Southern Alps and Carpathians. Turbiditic deposition, tectonic breccias, and synsedimentary faults testify thrust phenomena in the Padan foredeep, Vento Basin, and the Tuscan area. The Leitha orogenic phase further uplifted the Alpine – Carpathian – Dinarides chains. The most intensive nappe tectonics of the Carpathian region took place in this compressional cycle.

Carpathian-Pannonian realm

The lateral migration of the West Carpathian-Pannonian megablock, the last space reduction in the front of the Carpathian segment and the overthrusting of the outer nappe fronts to their modern position took place after the late Badenian. During the late Badenian, the Carpathian uplift slowed down, a marine regime was renewed and a new transgression began.

Marine sedimentation continued in the back-arc basins. The East Slovakian Basin was connected with the Transylvanian Basin through the Transcarpathian depression, and all these basins were connected with the central Pannonian area as well. In Transylvania and in front of the eastern Carpathians characteristic deep water pelites with plankton (radiolarian-bearing laminites, marly clays with *Spiratella*) were deposited. Part of the late Badenian deep water sediments are now covered by the Carpathian nappes due to the overthrusting movements.

Along the northern and eastern margins of the foredeep basin, on the Moldavian and Moesian platforms red-algal limestones and detrital and sandy sediments with rich coastal fauna were deposited. Thickness of the Upper Badenian sediments in this shallow part of the basin does not exceed 80 m. Subsidence influenced a rate of sedimentation which was most intensive in front of the central Carpathians and in some depressions in back-arc basins, where sediment thickness attains 1000–2000 m.

In the Pannonian area, the mantle diapir became active and took over the decisive role in the development of the Pannonian area and surrounding Carpathian regions (VASS 1979). The upper Badenian sediments are deposited discordantly and transgressively. Intense subsidence is significant for this period in the south part of the Great Hungarian Plain and Small Hungarian Plain and 300 m to 500 m of predominantly clayey marls were accumulated (HALMAI in CICHA et al. 1998). Algal reef limestones and sands with intercalated pelites were formed marginally.

The late Badenian is characterized by an exceptionally rich polyhaline warm water fauna and flora, including mollusks, corals, red algae, sea urchins, ostracods, and foraminifers. Nevertheless, on the basis of ecological demands of the fauna and flora, a climate colder than in the early Badenian was assumed (PLANDEROVA 1990). At the Badenian/Sarmatian boundary the fossil composition changed abruptly and polyhaline groups disappeared.

The volcanism was stronger than in the early Badenian. Submarine andesite volcanism predominated, especially in the south of the Apuseni Mountains, in back-arc basins, and along the central Hungarian line in the Pannonian depression. Andesitic-rhyolitic volcanics exceed thicknesses of 2000-3000 m in north Hungary – south Slovakia (HALMAI in CICHA et al. 1998).

Euxinian-Caspian Basin

The Konkian basin system extended from northeast Bulgaria and eastern slopes of Dobrogea to the Ustjurt and Kopetdagh. However, its size was reduced compared to the preceding Karaganian Basin.

The early Konkian Basin was inhabited by marine polyhaline fauna and phytoplankton, very similar to – though less diverse than – the Badenian biota. 97 bivalve and more than 50 gastropod species are known from the Konkian against 316 bivalves in the Upper Badenian (STUDENCKA et al. 1998) and about 1000 mollusk species in the whole Badenian. The distributional pattern of the Konkian mollusks indicates that the Eastern Paratethys was connected with the Mediterranean Tethys in its southeastern part, probably through the re-opened Araks Strait (GONTSCHAROVA & SHCHERBA 1997), and/or the Lesser Caucasus passage (ILYINA 2000b). The late Konkian (Veselanian) fauna was poorer than the early Konkian one, and it was dominated by euryhaline endemic species and subspecies, which were rare or unknown in the Badenian basin (*Acanthocardia andrussovi, Mactra basteroti konkensis, Parvivenus konkensis, Ervilia pusilla trigonula*). Salinity of the early Konkian sea was estimated to have been more than 30‰, and of the late Konkian – about 20‰ (MERKLIN 1953).

Shallow environments dominated over the Eastern Pararethys; relatively deep ones were preserved in the relict Western and Eastern Black Sea and South Caspian depressions and in the Indol – Kubanian and Terek – Caspian foredeeps. Detrital – shelly limestone and marls prevailed in the south Ukrainian and Turanian shelves and terrigenous sandy-clayey facies dominated in the central part of the Scythian and Transcaucasian shelves. Evaporitic layers (of gypsum composition) are widely spread along the eastern margin of the Konkian Basin and in the Turkish – Iranian middle Miocene.

The northern dryland was presumably low-lying; the main sources of coarse clastics were situated along the southern shoreline (Talysh, eastern Kopetdagh).

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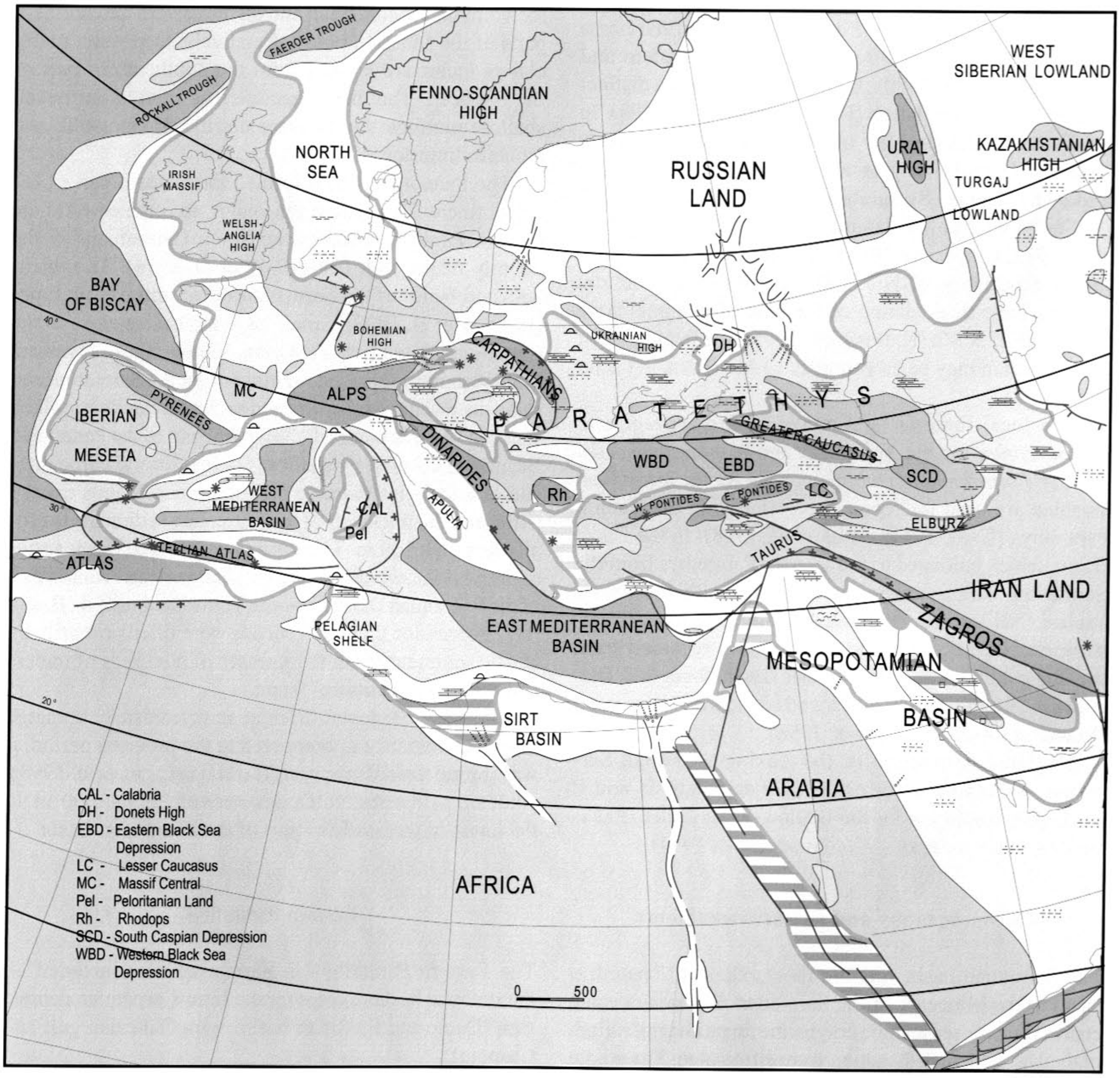
Map 7: Late Middle Miocene
(Late SERRAVALLIAN, SARMATION s.s., Middle SARMATION s.1) 12-11 Ma

Compiled by: N.P. Paramonova, I.G. Shcherba & S.O. Khondkarian

Co-authors: K. Gürs, J.I. Iosifova, T.V. Jakubovskaja, M. Kovac, I. Magyar, T.N. Pinchuk, S.V. Popov & A.S. Zastrozhnov



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Map 7: Late Middle Miocene (Late SERRAVALLIAN, SARMATIAN s.s.,Middle SARMATIAN s.l.)

Time slice definition and biochronology

The mapped intervals in the Central and Eastern Paratethys are not identical. In the Central Paratethys the mapped interval covers the entire Sarmatian s.s. (sensu BARBOT DE MARNY in SUESS 1866), which corresponds to lower and lower middle substages (sensu ANDRUSOV 1899 or Volhynian and lower Bessarabian – SIMIONESCU 1903) of the Eastern Paratethys Sarmatian s.l.. The upper Bessarabian and Khersonian (upper) substages of the Euxinian - Caspian Basin Sarmatian s.l. correlate with the Pannonian of the Central Paratethys. First appearance of the horse *Hipparion* in the upper Bessarabian of the Eastern and Pannonian zone "C" of the Central Paratethys is a distinct marker for this correlation (RÖGL in CICHA et al. 1998). In the Eastern Paratethys the mapped interval corresponds to the maximum transgression, which took place in the middle Sarmatian (Bessarabian).

The base of the Sarmatian was dated as 13.6 Ma (VASS et al. 1987, CHUMAKOV 1993). According to nannoplankton determination (NN6/7) and current Astronomical Polarity Time Scale dating of the base of mammal zone MN7/8 as 12,8 Ma (KRIJGSMANN 1995), the beginning of the Sarmatian may be as young as 13 Ma (RÖGL in CICHA et al. 1998).

The local foraminiferal zones *Elphidium reginum, E. hauerinum* for the Volhynian and *Nonion granosum* Zone [= *Porosononion (sub)granosum*] for the lower Bessarabian are used for regional correlation in the Central Paratethys (GRILL 1941, CICHA et al. 1998). In the Dacic Basin, which belonged to the Eastern Paratethys from the Sarmatian, nannoplankton assemblages with *Discoaster kugleri* (NN7) were recognized in the Volhynian; *Catinaster coalitus, C. calyculus* (NN8) were recorded from the upper Volhynian – lowermost Bessarabian and *Discoaster hamatus* (NN9) was identified in the Bessarabian (MARUNTEANU & PAPAIANOPOL 1998).

Regional correlation of the Euxinian-Caspian Sarmatian is based mainly on bivalve associations and it has higher resolution for the shallow-water facies (PARAMONOVA in ILYINA et al. 1976, PARAMONOVA 1994).

Paleogeography and paleoenvironments

The Sarmatian basin was the most extended Paratethys basin in the Miocene. In the Sarmatian the open oceanic connections closed and the polyhaline fauna and microflora of the late Badenian-Konkian were eliminated. The whole Paratethys was inhabited by homogeneous euryhaline biotas, with mainly endemic species, which evolved from the Badenian and Konkian ancestors. Systematic diversity of the Sarmatian endemics increased from the second part of the early Sarmatian through the mid-Sarmatian. Salinity had regionally specific composition. Based on bioecological data it was estimated as 16-18‰ in the Pannonian and Dacic basins and Galiczian Gulf and 14-15 ‰ in the Euxinian-Caspian Paratethys (KOJUMDGIEVA 1969).

Carpatho-Pannonian region

The lower Sarmatian (Volhynian) sea covered the whole eastern part of the Carpathian foredeep. But the Badenian-lowermost Sarmatian deposits were folded and thrust over the autochthonous Miocene in front of the central Carpathians. The mapped picture reflects a younger situation when the sea retreated eastward and was widespread on the Volhynian, Moldavian and on the eastern and northern parts of the Moesian plates. Relatively deep water marly clayey facies are known from the southeastern part of the foredeep. The most characteristic middle Sarmatian shallow platform facies were detrital organogenic and bioherm limestones.

The Pannonian Basin formed the western part of the epicontinental Sarmatian sea, and it was connected to the Eastern Paratethys across the South Carpathians in the vicinity of the Iron Gate (PAPP et al. 1974). The thickness and facies of the Sarmatian reflect three basin types (MAGYAR et al. 1999). Small back-arc basins close to the Carpathian thrust fronts (Styrian, Vienna, East Slovakian, Transylvanian) subsided rapidly during the Sarmatian and show deep water deposition and sediment thickness which exceeds 1 km. In contrast, the central part of the Pannonian Basin was covered by shallow sea; the littoral carbonates and clastic facies indicate that numerous islands existed there, and the thickness of the Sarmatian sediments is usually less than 100 m. The third type involved linear series of deep basins, which framed the shallow-water central part of the Pannonian Basin (western Transdanubia, Zala Basin, Sava depression). These trenches were filled primarily by clastic sediments with thicknesses of hundreds of meters and contain a sublittoral fauna.

The upper Badenian-Sarmatian volcanism culminated in the Sarmatian and, compared to the previous period, it was shifted towards the east (HALMAI in CICHA et al. 1998). Andesitic-rhyolitic volcanics exceed 2000–3000 m in thickness in the northern part of the Pannonian Basin.

Eastern Paratethys

The Eastern Paratethys in Sarmatian time included all Paratethyan basins except for the Intra-Carpathian depression (Dacic and Euxinian basins with Galiczian gulf and Caspian).

The Sarmatian Basin was strongly transgressed and transgression continued in the Bessarabian, especially on the northern and eastern margins, where it covered the north Pre-Caspian and the western part of the Turan Plate (KOLESNIKOV 1940). The Caucasus orogenic movements had led to coarser clastic sedimentation around the Greater Caucasus and local regressions in the Transcaucasia.

Deep water sedimentation continued in the Black-Sea, in the South Caspian depressions with the Kura Gulf, and in the Indol-Kubanian and Terek-Caspian foredeeps. Maximal thickness of clastics (up to 2000 m) is known from the Kura depression. Marly clays with *Cryptomactra* was the most usual facies in the shelfal depressions. Bryozoan bioherms were located on the top of the submarine escarpments.

Shallow environments with carbonate deposition dominated over the northern Eurasian shelf of the Eastern Paratethys and on the Turan Plate. On the Caucasian shelf, the primarily clayey sedimentation changed to sandy with typical mid-Sarmatian fauna (*Mactra, Obsoletiforma, Plicatiforma, Barbotella* among mollusks) from the second part of the Bessarabian. Terrigenous shelfal marine deposition prevailed in the Transcaucasia.

Based on the semimarine regime and nannoplankton associations with polyhaline zonal species in the Dacic basin, we propose communication between the Eastern Paratethys and the Mediterranean through the Aegean area. These temporal connections came to an end in the Khersonian, when the rich endemic Sarmatian biotas became extinct.

The Eastern European Platform was a lowland, which did not give abundant clastic material. Coarse molasse terrestrial deposits (up to 300 m) were accumulated along the eastern Kopet-Dagh and Pamir-Tien Shan zone.

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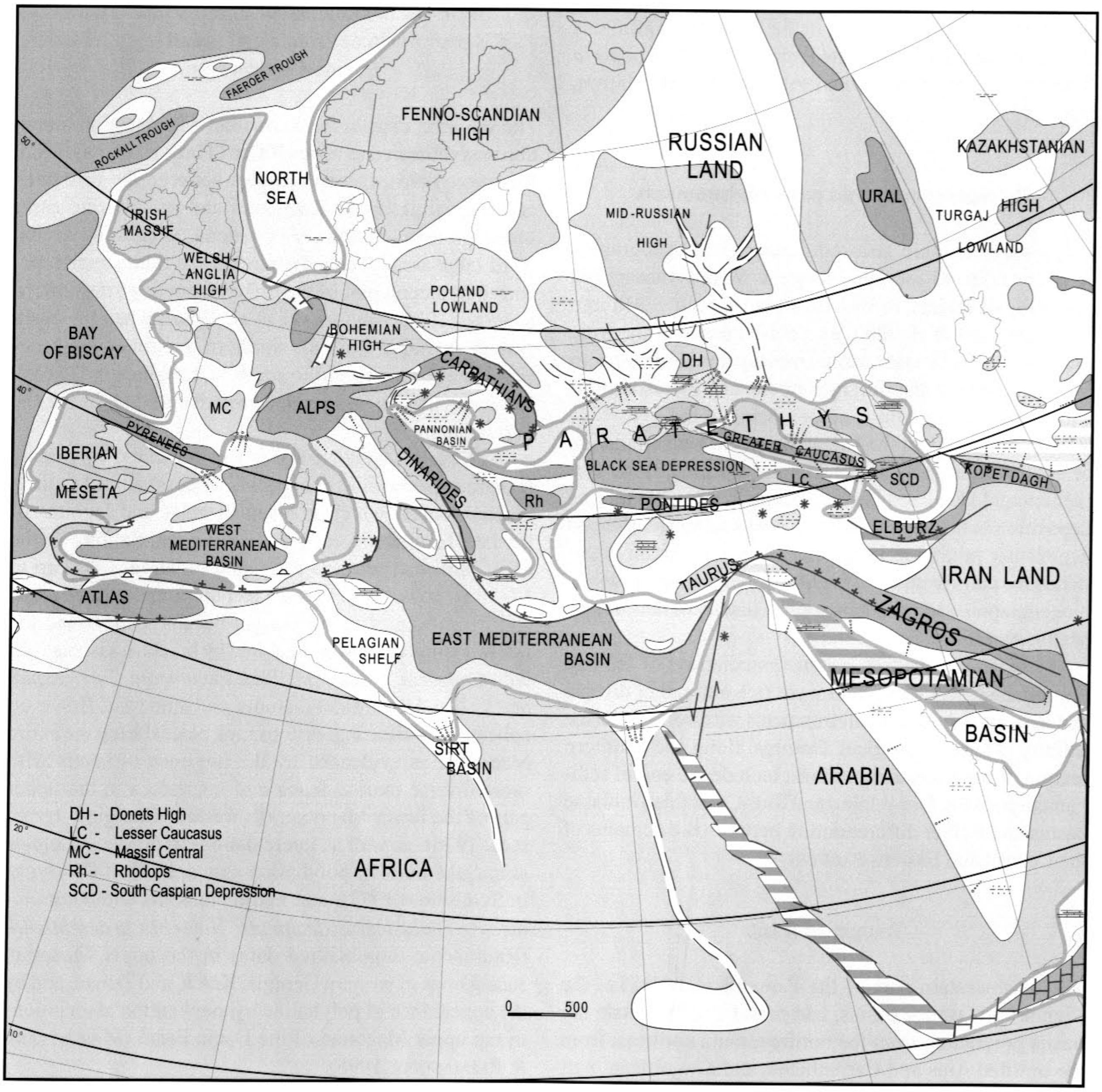
Map 8: Mid Late Miocene

(Late TORTONIAN – Early MESSINIAN, Early MAEOTIAN, Late PANNONIAN) 8,5-7 Ma

Compiled by: L.B. ILYINA, I.G. SHCHERBA & S.O. KHONDKARIAN

Co-authors: K. GÜRS, J.I. IOSIFOVA, T.V. JAKUBOVSKAJA, M. KOVAC, I. MAGYAR, T.N. PINCHUK & S.V. POPOV



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Map 8: Mid Late Miocene
(Late TORTONIAN – Early MESSINIAN, Early MAEOTIAN, Late PANNONIAN)

Time slice definition and biochronology

Correlation of the Maeotian with the Mediterranean scale is one of the most questionable points in the Paratethyan stratigraphy. The most usual correlation proposed correspondence of the Maeotian with the middle – upper Tortonian (ILYINA & NEVESSKAJA 1979, MURATOV & NEVESSKAYA 1986, RÖGL 1998). According to recent magnetostratigraphic and nannofossil research (NN11) and correlation with the current Astronomical Polarity Time Scale (SNEL et al. 2001) the Maeotian has to correlate with the uppermost Tortonian – lower Messinian. In the Pannonian Basin this interval corresponds to the late Pannonian, early *Congeria rhomboidea*, early *Galeacysta etrusca* biochrons (MAGYAR et al. 1999).

Paleogeography and paleoenvironments

Large-scale tectonic and sedimentary-paleogeographic turnover affected the late Neogene Mediterranean and Paratethyan realms in the Tortonian (about 8 Ma ago – MEULENKAMP et al. 2000) as a consequence of the Attic orogenesis. Horizontal tectonic movements in the western Mediterranean, with uplift in the Betic and Rifean regions and consequent shoaling and/or closing of the Betic Corridor and shoaling of the Rifean Strait with accumulation of evaporites from the late Tortonian, opening of the Tyrrhenian and Dead Sea basins, inception of stable marine deposition in the Aegean domain, and southward directed depocenter migration in the fore-Apennine Basin determined the main features of the Messinian paleogeographic, biogeographic and sedimentological history of the circum-Mediterranean realm.

Planktic and shallow benthic associations of the late Tortonian – early Messinian were rich and rather diverse and indicate subtropical environments with normal marine salinity. Major geological features along the southern margin of the European platform include the end of sedimentation in the fore-Alpine and fore-Carpathian molasse basins and further differentiation between the domains of the Central and Eastern Paratethys.

Pannonian Basin

The northwestern part of the Pannonian Basin, i.e. the Vienna and Danube basins, had been filled by deltaic deposits prograding from the northwest and northeast from the uplifted Alps and Carpathians, and a significant part of the basin had been transformed into alluvial plains by late Pannonian times (MAGYAR et al. 1999). The Transylvanian Basin also dried up, so Lake Pannon was restricted to the southern part of the basin, where several hundred meter deep subbasins existed. The deep basins were filled up by prodelta turbidites and then by prograding deltaic sediments. The southern shoreline, running parallel with the Sava and Danube rivers along the northern foots of the Dinarides, changed very little during the lifetime of Lake Pannon.

Whether the lacustrine basin ever experienced marine water incursions is ambiguous. Rare and sporadic findings of polyhaline nannofossils (KOLLANYI 2000) and presence of supposedly marine elements in dinocyst associations (SUTO 1995) seem to suggest that marine connections were not fully lost. However, the benthic fauna of mollusks and ostracods was almost fully endemic, and reflects a constant brackish lacustrine environment (MÜLLER et al. 1999).

Euxine-Caspian Basin

The sea level drop at the Sarmatian s.l.-Maeotian transition was estimated as about 300 m (TUGOLESOV et al. 1985, ROBINSON 1995). Unconformities between the freshened or hypersaline upper Sarmatian and semimarine early Maeotian deposits are very common, suggesting drying up of large areas. The maximum of the transgression occurred in second part of the early Maeotian (STEVANOVICH & ILYINA 1982, NEVESSKAYA et al. 1986), when the basin system extended from the northern margin of the Moesian Plate (Dacic Basin) to south Mangyshlak in the east. However, its size was reduced relative to that during the Sarmatian.

The early Maeotian Basin was inhabited by mainly endemic species and subspecies of euryhaline Mediterranean genera, which evolved in gulfs and lagoons of the late Tortonian – early Messinian sea. Salinity of the early Maeotian sea was estimated to be 13–14‰, up to 17–18‰ (ILYINA et al. 1976). Later this impoverished fauna and microflora of marine origin became extinct and the late Maeotian basin was inhabited by brackish associations with *Congeria, Theodoxus, Pseudoamnicola, Turricaspia*, brackish and freshwater diatoms, and dinocysts. However, ephemeral marine ingressions took place during the entire Maeotian, as evidenced by the presence of layers with more diverse marine fauna and microflora in the upper part of the lower Maeotian (in western Georgia – ILYINA et al. 1976), as well as intercalations with *Mactra superstes, Spheronassa*, polyhaline nannoplankton (LULIYEVA in SEMENENKO 1987), and marine diatoms with *Coscinodiscus, Thalasiosira decipiens, Nitzschia praereinholdi* (Radionova, unpublished data) in the upper Maeotian successions of western Georgia, Kerch, and Taman, and by the appearance of polyhaline nannoplankton associations in the upper Maeotian of the Dacic Basin (MARUNTEANU & PAPAIANOPOL 1998).

Connections with the Mediterranean are proposed in the Aegean region, where lagoonal mollusk associations of the lower Messinian (North Greece, Serres, Dafni Formation) are very similar to the lower Maeotian mollusks (Stevanovich & Ilyina 1982, Popov & Nevesskaya 2000).

Shallow environments dominated over the Eastern Paratethys, deep water ones existed only in the Black Sea and South Caspian depressions and relatively deep water (more then 200–300m) in the Indol-Kubanian and Terek-Caspian foredeeps. In much of the Eurasian shelf, shallow limestones, clays, and sands accumulated. Oolitic and detrital - shelly limestones developed in the south Ukraine, Crimea, Azov area and south Mangyshlak. Alluvial-deltaic deposition prevailed around growing orogenic structures of the Greater Caucasus and along the northern margin of the Euxinian Sea (Shcherba et al. 2001).

The east European platform represented a lowland with the mid-Russian High in its centre, and the Volhynian, Ukrainian and Donets highs in its southern parts. Thick clastic molasse deposits were accumulated in continental-coastal areas of the Transcaucasia – in the Kura and Rioni depressions. The Turan Plate became a lowland mainly without deposition. Orogenic movements in the Kopetdagh and Pamir-Tien Shan zone led to the appearance of a spacious molasse belt along their foothills, composed of course-clastic red-colored sequences (Shcherba 1993, Shcherba et al. 2001).

Based on biogeographical data (full sets of the early Maeotian-Pontian mollusks and ostracods in the Azerbaijan and South Mangyshlak associations), we proposed that at least temporary communications existed between the Euxinian and Caspian basins in the Transcaucasia before the late Pontian (Nevesskaya et al. 1986). The connection could have been located between the Adzharo-Trialeti fault system, which came to its modern position in the late Kimmerian, and the southern border of the Dzirul Massif.

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Map 9: Latest Miocene
(Late MESSINIAN, Early PONTIAN – Late PANNONIAN) 6,1-5,7 Ma

Compiled by: S.O. KHONDKARIAN, I.G. SHCHERBA & S.V. POPOV

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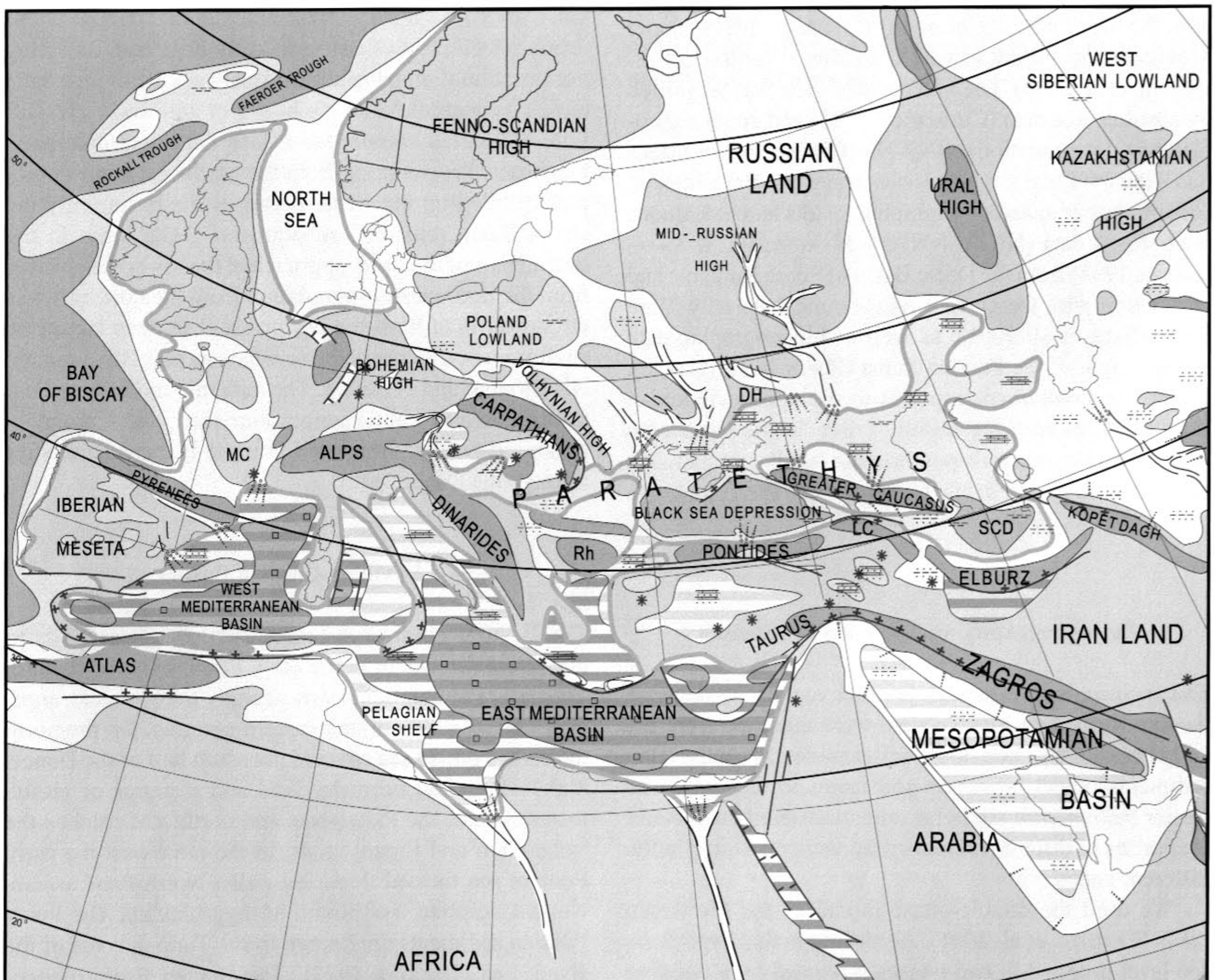

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Map 9: Latest Miocene (Late MESSINIAN, Early PONTIAN – Late PANNONIAN)

Time slice definition and biochronology

Correlation of the Pontian with the Mediterranean scale is disputable. The most usual correlation proposed correspondence of the Pontian with the entire Messinian (ILJINA & NEVESSKAJA 1979, MURATOV & NEVESSKAYA 1986, RÖGL 1998). This correlation, however, is contradicted by the paleomagnetic data. Based on primary reversed polarity of the Pontian, it is possible to correlate it with Chron 6 of the Harland scale and with the upper Tortonian – lower Messinian, as proposed by M.A.Pevzner, or alternatively with the lower part of Chron 4 (=C3r) and with the upper Messinian, according to V.M.Trubikhin (PONTIEN in STEVANOVIC et al. 2000). The first point of view was supported by absolute age data (CHUMAKOV 1993) and zonal nannoplankton determinations (NN9-NN10 in base of the Maeotian – data of LULIYEVA in SEMENENKO 1987). Nevertheless, according to magnetostratigraphic results and calcareous nannofossil data (NN11, NN12 – MARUNTEANU & PAPAIANOPOL 1998) from the Dacic Basin of South Romania and correlation with the current Astronomical Polarity Time Scale (SNEL et al. 2001), as well as biogeographic data on the origin of the Pontian fauna (POPOV & NEVESSKAYA 2000), the Pontian corresponds to the upper Messinian and correlates with the salinity crisis. In the Pannonian Basin this interval corresponds to the late Pannonian, late *Congeria rhomboidea*, late *Galeacysta etrusca* biochrons (MAGYAR et al. 1999).

Paleogeography and paleoenvironments

The main paleogeographic features and bathymetry of the late Messinian basin system were inherited from the early Messinian. The salinity crisis markedly changed the sedimentological processes and facies in the basin; the earlier bathymetric zones became more distinct, because evaporites of different composition were deposited in the different zones.

We used the double-phase model of the Messinian crisis (CLAUZON et al. 2001). According to this hypothesis sea level dropped in two phases separated by a flooding event. The first phase (5.8 Ma) affected only the Mediterranean basin margins and led to accumulation of the lower evaporites of gypsum composition. The second phase, characterized by a drastic sea level drop exceeding 1500 m, affected the whole basin (5.6 Ma). As a consequence, deep canyons were incised in the basin margins (paleo-Nile, Rhone, Ebro et al.) and thick evaporate series (up to 2 km according to seismic data) were accumulated in the bathyal plains. Between the two phases brackish deposition of "Lago Mare" facies took place. We try to reflect all this complex history on a single map.

The brackish fauna and microflora of the "Lago Mare" facies included numerous genera and species, common with the Paratethys: endemic limnocardiins, *Congeria, Melanopsis* among mollusks, *Loxoconcha djaffarovi* ostracod association, *Galeacysta etrusca* among dinocysts. The origin of this assemblage was probably connected with more ancient – Pannonian-Paratethyan biota, but their subsequent development unfolded independently. Some components of this specific biota, together with more rare Pannonian elements, were ancestral for the younger Pontian fauna of the Euxinian-Caspian Paratethys; they moved from the Mediterranean to the Eastern Paratethys through intermediate basins (Aegean, Dacic) (EBERZIN 1949, NEVESSKAYA et al. 1986, POPOV & NEVESSKAYA 2000).

Pannonian Basin

Late *Congeria rhomboidea*, late *Galeacysta etrusca* biochrons. Progradation from the northwest almost completely filled up the western part of the basin; only the Drava Basin remained subaqueous. Delta lobes in the central part of the basin approached the lower Tisza River from the northwest. Progradation from the northeast was far slower than from the northwest. The deep lacustrine environment was restricted to what are now SE Hungary, NE Croatia, and N Serbia. The endemic mollusk and ostracod fauna of Lake Pannon flourished, and – probably in several pulses – migrated into the Eastern Paratethys through the Dacic Basin.

Euxinian-Caspian Basin

The Eastern Paratethys reconstruction corresponds to maximum sea extent in the early Pontian (Novorossian). The early Pontian Basin was strongly transgressed, especially on its northern and eastern margins. On the north the early Pontian sea covered the south half of the Donets high, which had been dry land and a source of clastic material since the Paleogene, and northward reached the Volga-Don and Ergeni areas. In the northwest the early Pontian sea formed three big gulfs: North-Pre-Caspian, North-Ustjurtian, and South Mangyshlakian. The lower Pontian sediments are known in the Turkish coast of the Black Sea (ÖSZAYAR 1977). The Dacian Basin biogeographically belonged to the Eastern Paratethys.

Sandy deposition prevailed in its shallow coastal areas and muddy sedimentation in deeper environments. Calcareous, shelly-detrital facies were widespread on the northern inner shelf of the Euxinian-Caspian Basin. Towards the Caucasus, Kopetdagh and western clastic sources the facies changed to muddy and sandy deposits. Deep water environments existed only in the Black Sea and South Caspian depressions.

Based on the prevailingly brackish fauna, salinity of the basin was low, but didn't fall under 5–8‰. The Dacian part, where *Parvivenus widhalmi* – the single bivalve species of marine origin in Eastern Paratethyan Pontian – was absent, was probably more freshened. At the same time the presence of nannoplankton zonal associations (MARUNTEANU & PAPAIANOPOL 1998) in the middle (NN11) and upper (NN12) Pontian testifies to episodic ingressions of marine waters. Connection probably took place via the Aegean Gulf of the late Messinian sea (STEVANOVIC et al. 1989, POPOV & NEVESSKAYA 2000).

A sharp regression at the beginning of the late Pontian (Portaferrian) led to the drying of the northern outer shelf of the Euxinian Basin. The Stavropolian Strait was closed, the Caspian Basin was separated from the Euxinian one in its northern part, and the eastern lake-sea became restricted to the modern Middle and South Caspian with the Kura gulf. The date of this sea level fall approximately correlates with the drastic sea level drop in the Mediterranean (5.7 Ma, according to TRUBIKHIN in STEVANOVIC et al. and 5.6 Ma by MEULENKAMP et al. 2000). According to biogeographic data, however, the Caspian-Euxinian connection was maintained during the entire Pontian: specific late Pontian species common in the Euxinian and Dacian basins are known from the upper Pontian of Azerbaijan (NEVESSKAYA et al. 1986).

The east European platform represented a lowland with the mid Russian High in its central part. Thick clastic molasse deposits were accumulated in continental – coastal areas of the Transcaucasia-in the Kura and Rioni depressions. Conglomerates, clays, and sands of the Dushet Formation (Maeotian-Pontian, up to 2000 m) were accumulated in fluvial environments, containing remains of terrestrial and freshwater mollusks, mammals, and plants. Rivers that transported this material discharged into a lake in the mid-Kura depression, where low-carbonate sandy clays (up to 2500 m) of the Maeotian-Pontian Shirak Formation were deposited. The Turan Plate became a lowland mainly without deposition.

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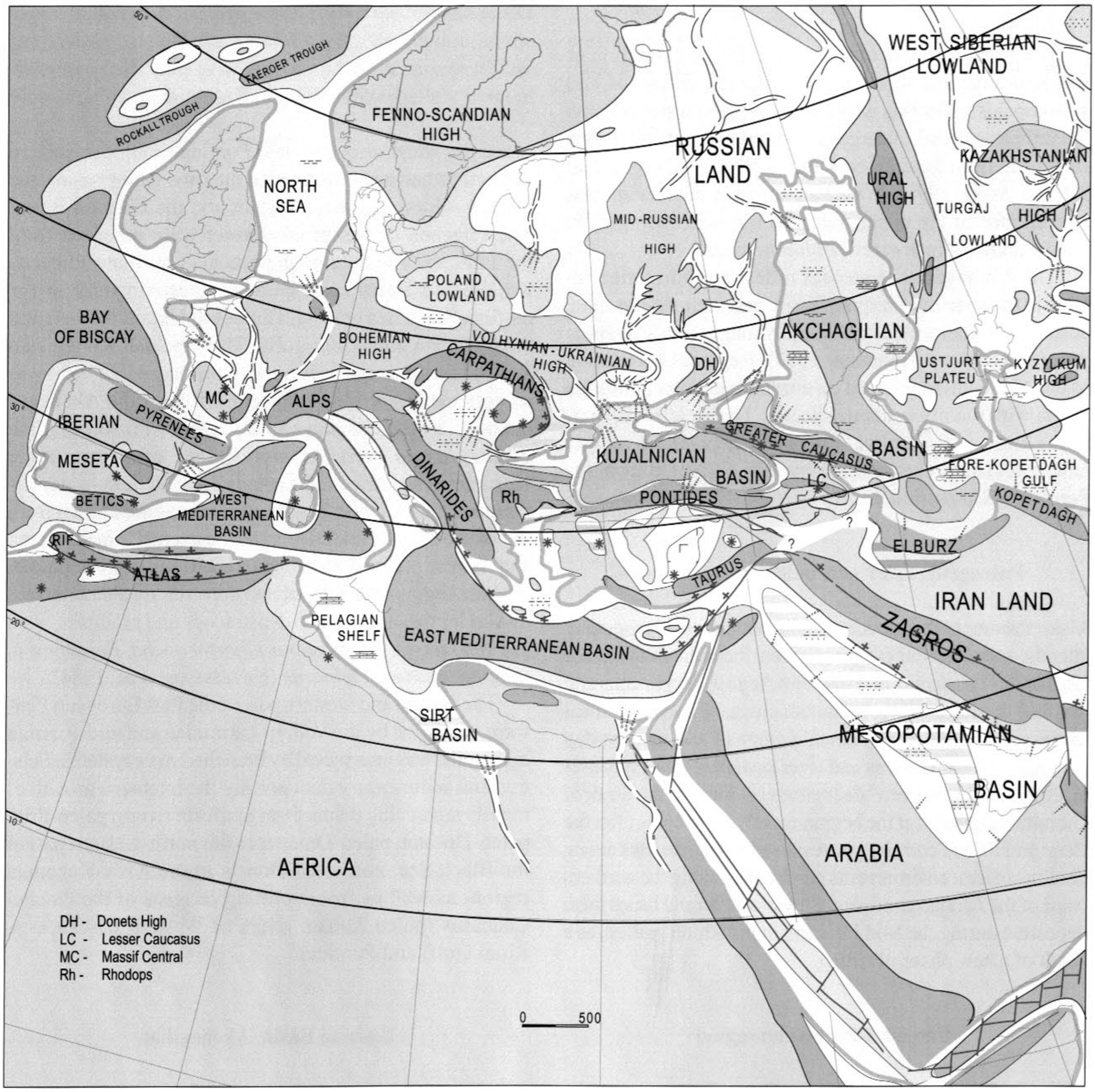
Map 10: Middle-Late Pliocene
(PIACENTIAN – GELASIAN, Late ROMANIAN – AKCHAGILIAN) 3,4-1,8 Ma

Compiled by: S.O. KHONDKARIAN, N.P. PARAMONOVA & I.G. SHCHERBA

Co-authors: K. GÜRS, J.I. IOSIFOVA, T.V. JAKUBOVSKAJA, M. KOVAC, I. MAGYAR, T.N. PINCHUK, S.V. POPOV & A.S. ZASTROZHNOV



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Map 10: Middle-Late Pliocene (PIACENTIAN – GELASIAN, Late ROMANIAN – AKCHAGILIAN)

Time slice definition and biochronology

Due to the non-marine character of many younger Pliocene Peri-Tethyan sequences it is often not possible to subdivide the middle/upper Pliocene. So the Pliocene map reflects a broad time-interval from about 3.4 to 1.8 Ma and displays paleogeographic configuration and environments that occurred after the late Early Pliocene large-scale tectonic reorganization. In terms of regional Paratethys stages and horizons, it corresponds to the Romanian of the Dacic Basin, the Kujalnician of the Euxinian Basin, and the Akchagilian of the Caspian Basin.

The Romanian was characterized by the extinction of limnocardiines and appearance of unionids, viviparids, and melanopsids, reflecting a further decrease in water salinity. Nevertheless, zonal calcareous nannoplankton associations are known from these layers (NN15–NN16 – MARUNTEANU & PAPAIANOPOL 1998). In the Pannonian Basin this interval corresponds to the upper part of the geochronologically poorly defined freshwater "*Paludina* beds".

The Akchagilian sequences reflect a semi-marine regime in the spacious Caspian Basin, and their stratigraphic position is rather well established by magnetostratigraphic data (C2+C2An – TRUBIKHIN 1977). Regional correlation of the Akchagilian is based on euryhaline fauna of marine origin with mainly endemic species. The Kujalnician part of the Eastern Paratethys differs in the presence of specific brackish mollusks and ostracods, inherited from the Pontian – Kimmerian fauna.

Paleogeography and paleoenvironments

Major features of the circum – Mediterranean paleogeography after the early Pliocene orogenesis were increasing subsidence rates of the Tyrrhenian and southern Aegean depressions and uplift of the surrounding mountain chains. Pliocene vertical movements initiated the development of the present-day paleogeographic features and river system (MEULENKAMP et al. 2000). In the western Mediterranean domain, the Strait of Gibraltar originated at the beginning of the Pliocene, after the Betic and Rifean corridors were closed in the late Messinian. Shallow marine environments persisted all along the northern coast of the African continent. Fluvial and limnic facies were deposited during the Mid Pliocene in the Rhine graben, as a result of a new phase of rifting.

Carpatho-Pannonian region

Major folding and thrusting in the Outer Carpathians came to an end by the late Pliocene. In the intra-Carpathian domains, accumulation of continental clastics took place in local depressions during the Mid to Late Pliocene. However, in the southwestern part, the Drava and Sava basins were filled by Pliocene deposits, which reached to about 1000 m (MEULENKAMP et al. 1996). The Plio-Pleistocene alkali-basaltic volcanism played an important role in the intra-arc domains and occurred in the Styrian and Danube basins, Great Hungarian Lowland, Transylvania and Slovakian-Hungarian volcanic domain (SZABO et al. 1992).

Brackish and fluvio-lacustrine foredeep sedimentation continued only in the southeast in the Dacic Basin, where the Pliocene (Dacian-Romanian) sequences reach thicknesses of thousands of meters. Ephemeral brackish-water ingressions came from the adjacent Euxinian domain only in the eastern part of the overall fluvio-lacustrine Dacic basin.

Euxinian Basin, Kujalnician

Since the latest Miocene (late Pontian time), the Eastern Paratethys had been subdivided into two major basins, the Dacian – Euxinian basin system and the Caspian Basin. The Pliocene faunas of the former were inherited from the Pontian. The area of the brackish mid-late Pliocene Kujalnician Basin corresponded approximately to the modern Black Sea area with the south Ukrainian shelf and Azov-Kuban and Rioni gulfs. The brackish Kujalnician Sea had no direct connection with the ocean, but there was an ephemeral corridor connecting it with the Akchagilian basin of the Caspian region: layers with Akchagilian *Avimactra* and *Cerastoderma dombra* are known in the Kujalnician sequences of the Azov area. Shallow-water terrigenous clastics with Kujalnician faunas are known from the North Black Sea Depression, eastern Crimea, Kerch and Taman peninsulas, Kuban and Rioni depressions. In all these regions the Kujalnician deposits are characterized by similar fossils of brackish ostracods and mollusks, such us *Prosodacna, Pachydacna, Chartoconcha, Pontalmyra, Oraphocardium, Viviparus* (NEVESSKAJA et al. 1984).

The central and western part of the East European Platform, occupied by the Volhyn-Ukrainian and mid-Russian highlands, was intersected by branched river systems. Seismic and sedimentary data portray the intensive growth of rapidly advancing deltas from platform rivers (paleo-Prut, paleo-Dnester, paleo-Dnieper in the north-western part of the Black Sea, and paleo-Donets in the Azov-Kubanian region) as well as from uplifting orogens of the Greater Caucasus (paleo-Kuban, rivers of Western Ciscaucasia, Rioni Gulf) and Pontides.

Caspian Basin, Akchagilian

The pre-Akchagilian Balakhanian freshwater basin was restricted to the South Caspian depression and the Kura

Gulf. The lowering of sea level resulted in deeply incised valleys (up to a few hundred meters) of the paleo-Volga, paleo-Kura and paleo-Amudarja rivers. The Akchagilian Sea invaded this rugged relief. It was characterized by a hemi-marine regime with reduced salinity and euryhaline biota of marine origin. Numerous endemic taxa (genera and species) of mollusks, ostracods and diatoms evolved from lagoonal Mediterranean ancestors. The place of connection with the Mediterranean remains highly speculative. Polyhaline nannoplankton associations from Azerbaijan and brackish-marine Pliocene deposits from eastern Turkey (upper Euphrates valley – STEININGER et al. 1985, CHEPALYGA 1995) show a possible corridor from the eastern Mediterranean to eastern Transcaucasia or the South Caspian depression.

Relatively deep-water, clayey deposits (up to 350–500 m) accumulated in the entire central part of the basin from the pre-Caspian area to the South Caspian depression, in the Kobystan part of the Lower Kura and the deep-water Fore-Kopetdagh depressions. In the relatively shallow parts of the southern marginal areas of the basin, terrigenous and calcareous sediments with rich endemic faunas (*Avicardium, Miricardium, Andrussella, Avimactra* - PARAMONOVA 1994) were deposited in mid-Akchagilian time.

Northwards, the Akchagilian Sea ingressed eventually the Volga and Kama basins. Poor and uniform, euryhaline faunas in the northern parts of the basin system reflect reduced salinities as compared to those of the main basin. During the mid-Akchagilian, marine ingressions reached as far as the paleo-Murgab, Tedzhen and Amudarja valleys and the south Aral Gulf.

A new phase of orogenic movements resulted in a pronounced increase of clastic supply from the evolving chain towards the bordering plains. The coarsest molasse-type clastics were laid down around the Greater Caucasus, Eastern Kopetdagh, Pamir and Tien Shan orogenic belts.

Eruptions in the Kazbek area of the Central Caucasus and Adzharo – Trialet Ridge produced abundant volcanoclastics (MURATOV & NEVESSKAYA 1986).

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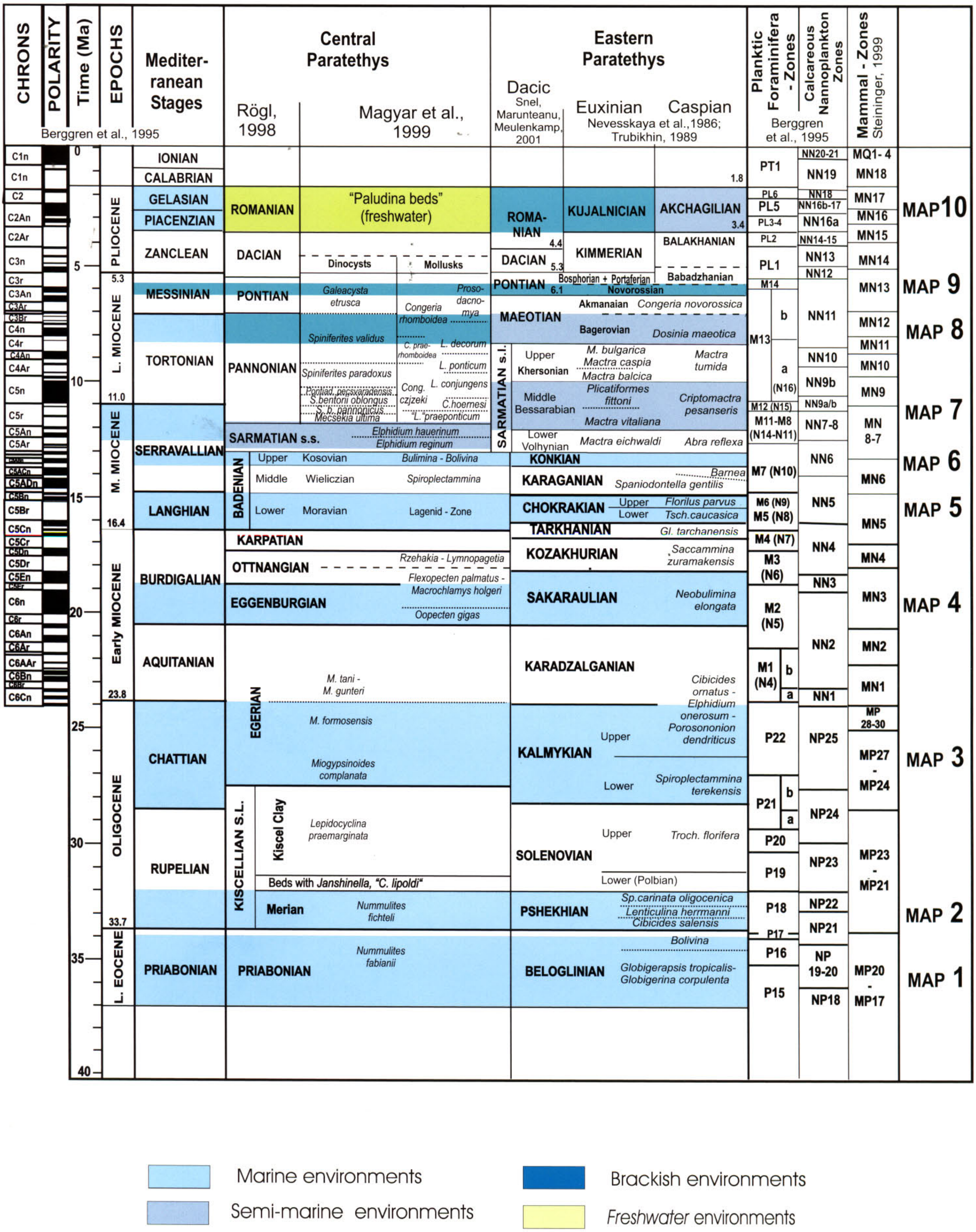
Stratigraphic scheme of the Late Paleogene - Neogene Paratethys and mapped intervals



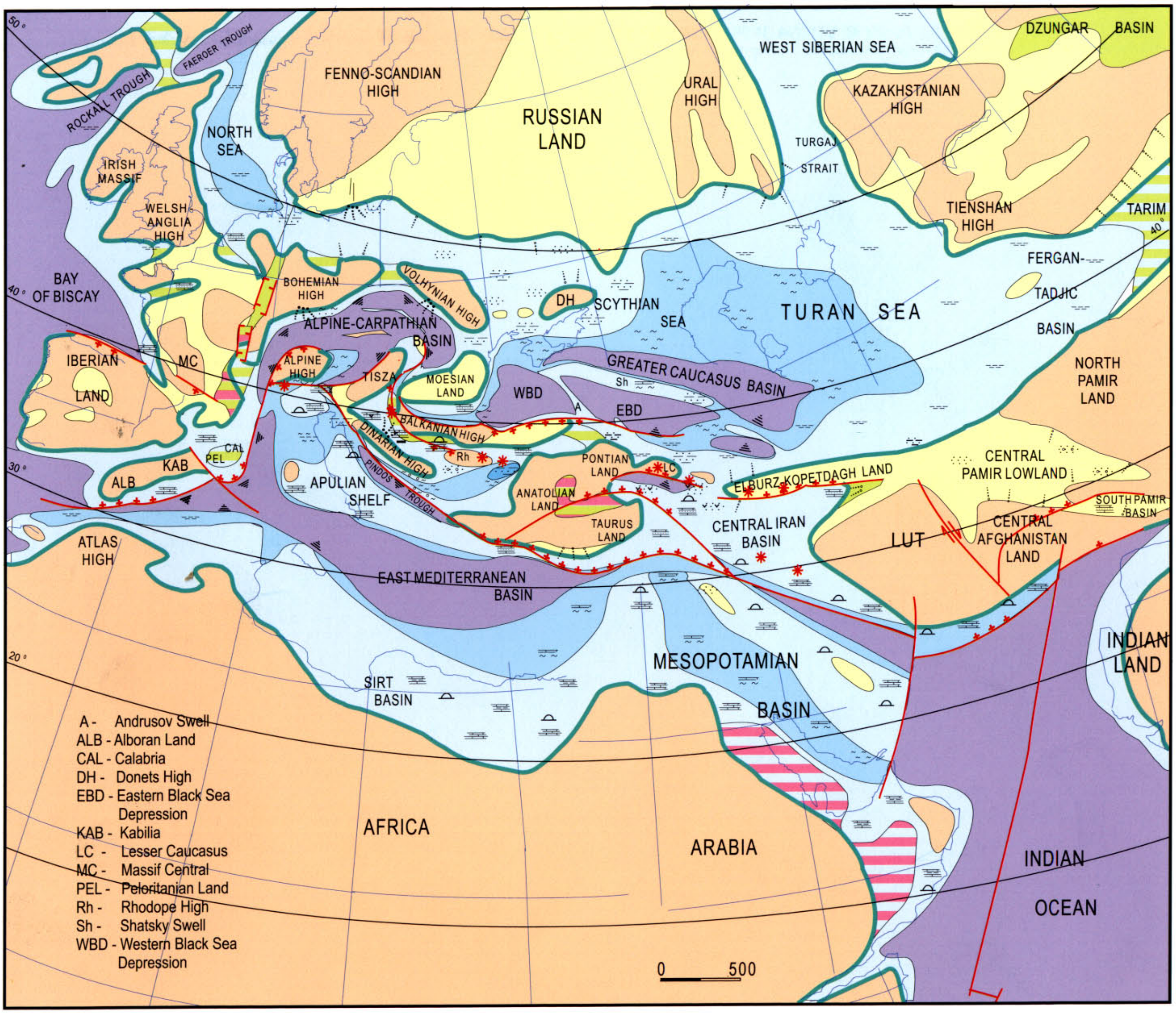
Lithological-Paleogeographic maps of Paratethys

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

Co-authors: K. Gürs, M. Kovac, V.A. Krasheninnikov,
A. Nagymarosy, B.I. Pinkhasov, F. Rögl, A. Rusu

Map 1

Late Eocene
37-34 Ma



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Map 1. Late Eocene *(PRIABONIAN - BELOGLINIAN)*

Legend

I. LITHOLOGY:

Breccia
Conglomerate
Sand and sandstone
Silt and siltstone
Clay
Marl
Limestone
Silicilith
Intrusive massif
Terrigenious flysch
Calcareous flysch
Anhydrite and gypsum
Ashes and tuff material

II. MINERAL RESOURCES

Coal
Chloritic salts
Oil and gas

III. PALEOGEOGRAPHY

Marine environments:

Shallow shelf
Deep shelf
Deep shelfal depression
Continental slope, basin bottom

Continental environments:

Freshwater lake, marsh
Lowland
Highland
Mountain range
a b *Paleogeographic boundary, a - established, b - inferred*
Lithofacies boundary
Present-day limit of deposits
Sea - continent transition
Bioherm
Delta, pro-delta, fan
Turbidites
Volcano
Sediment supply
·75 ·(650) *Thickness in meters , established and aproximate*
10 *Isopach in meters*
Syn-sedimentary fault, flexure
a b *Overthrust: a - synsedimentary, b - postsedimentary*
a b *Strike-slip fault: a - synsedimentary, b - postsedimentary*

Published and unpublished materials were used:

Andjelkovic et al. 1991; Baldi 1986; Balla 1984; Chekunov et al. 1976; Csontos et al. 1992; Dercourt et al. 1985; Dercourt et al. 1993; Dercourt et al. 2000; Gansser 1957; Goff et al. 1995; Jones & Racey 1994; Karasev 1948; Kovac et al. 2002; Kopp & Shcherba 1998; Luttig & Steffens 1976; Nagymarosy 1990; Poisson et al. 1997; Ponikarov et al. 1968; Rögl 1998; Rögl & Steininger 1983; Sandulescu & Micu 1988; Shcherba 1993; Sissingh 2001; Steininger & Wessely 2000; Stolyarov 1991; Stolyarov et al. 1996; Tugolesov et al. 1985; Vinogradov 1967-1969; Wagner 1996; Ziegler 1990.

Map 1: Late Eocene (Priabonian Beloglinian). In: Popov, S.V., Rögl, F., Rozanov, A.Yu., Steininger, F.F., Shcherba, I.G. & Kovac, M. (2004): Lithological-Paleogeographic maps of Paratethys. Courier Forschungsinstitut Senckenberg, 250: 1-46; maps 1-10.

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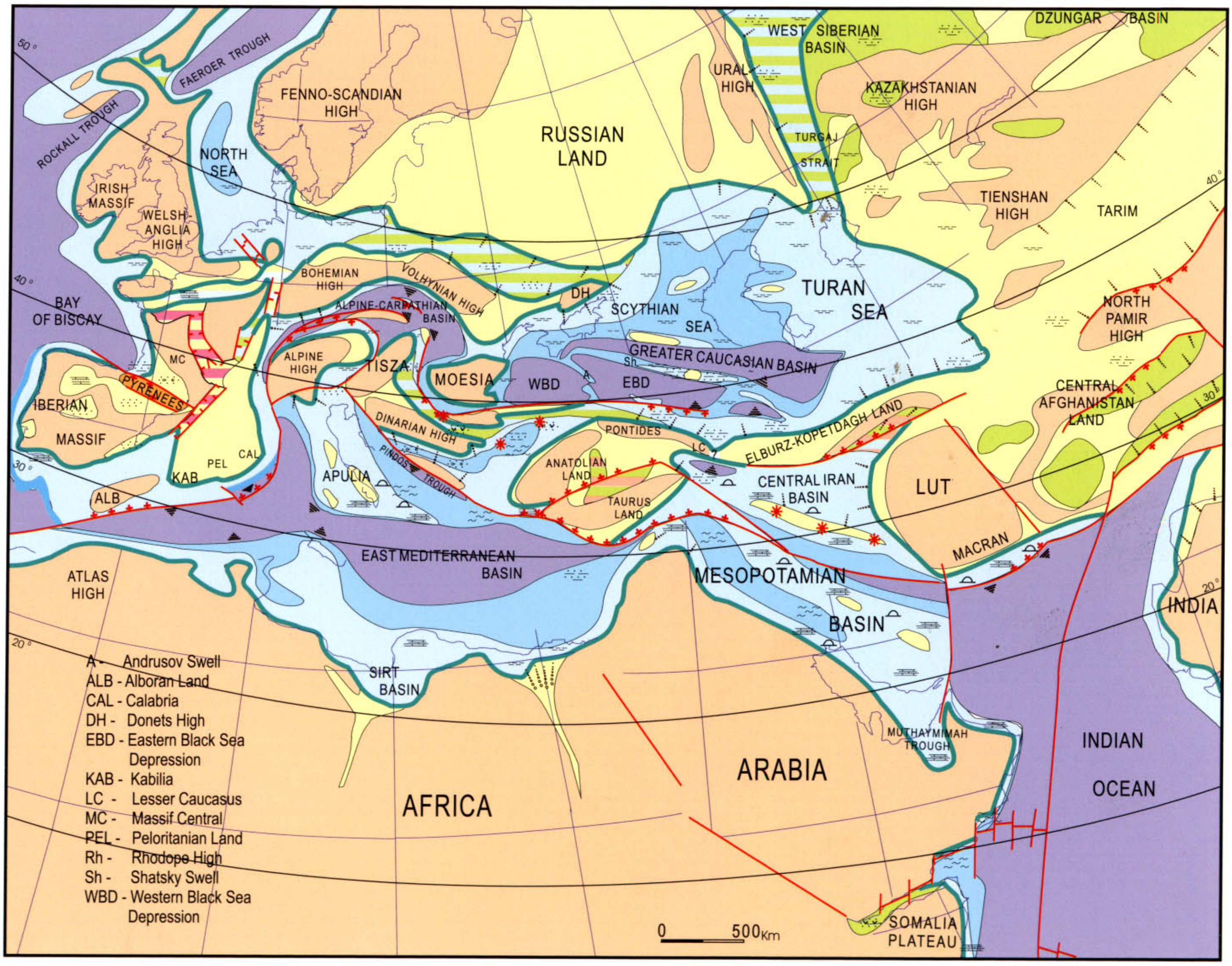
A. Nagymarosy, B.I. Pinkhasov, F. Rögl, A. Rusu

Map 2

Early Oligocene

34-32 Ma



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Map 2. Early Oligocene *(Early RUPELIAN, Early KISCELLIAN- PSCHEKHIAN)*

Legend

I. LITHOLOGY:

- *Breccia*
- *Conglomerate*
- *Sand and sandstone*
- *Silt and siltstone*
- *Clay*
- *Anoxic clay*
- *Marl*
- *Limestone*
- *Silicilith*
- *Intrusive massif*
- *Terrigenous flysch*
- *Anhydrite and gypsum*

II. MINERAL RESOURCES

- *Coal*
- *Oil and gas*
- Mn *Manganese*
- U *Uranium and rare earth*
- *Ferruginous*

III. PALEOGEOGRAPHY

Marine environments:

- *Shallow shelf*
- *Deep shelf*
- *Deep shelfal depression*
- *Continental slope, basin bottom*

Continental environments:

- *Freshwater lake, marsh*
- *Lowland*
- *Highland*
- *Mountain range*
- a, b *Paleogeographic boundary, a - established, b - inferred*
- *Lithofacies boundary*
- *Present-day limit of deposits*
- *Sea - continent transition*
- *Bioherm*
- *Delta, pro-delta, fan*
- *Turbidites*
- *Volcano*
- *Sediment supply*
- 75, (650) *Thickness in meters , established and aproximate*
- 10 *Isopach in meters*
- *Synsedimentary fault, flexure*
- a, b *Overthrust: a - synsedimentary, b - postsedimentary*
- a, b *Strike-slip fault: a - synsedimentary, b - postsedimentary*

Published and unpublished materials were used:

Andjelkovic et al. 1991; Baldi 1986; Balla 1984; Berger 1996; Chekunov et al. 1976; Csontos et al. 1992; Dercourt et al. 1985; Dercourt et al. 1993; Dercourt et al. 2000; Furrer & Soder 1955; Gansser 1957; Goff et al. 1995; Jones & Racey 1994; Karasev 1948; Kopp & Shcherba 1998; Kovac et al. 2002; Luttig & Steffens 1976; Nagymarosy 1990; Nagymarosy & Baldi-Beke 1993; Poisson et al. 1997; Ponikarov et al. 1968; Rögl 1998; Rögl & Steininger 1983; Saidov & Kuschanin 1947; Sandulescu & Micu 1988; Shcherba 1993; Sissingh 2001; Steininger & Wessely 2000; Stolyarov 1991; Stolyarov et al. 1996; Tugolesov et al. 1985; Vinogradov 1967-1969; Wagner 1996; Yetis et al. 1995; Ziegler 1990.

Map 2: Early Oligocene (Early Rupelian, Early Kiscellian-Pschekhian). In: Popov, S.V., Rögl, F., Rozanov, A.Yu., Steininger, F.F., Shcherba, I.G. & Kovac, M. (2004): Lithological-Paleogeographic maps of Paratethys. Courier Forschungsinstitut Senckenberg, 250: 1-46; maps 1-10.

Lithological-Paleogeographic maps of Paratethys

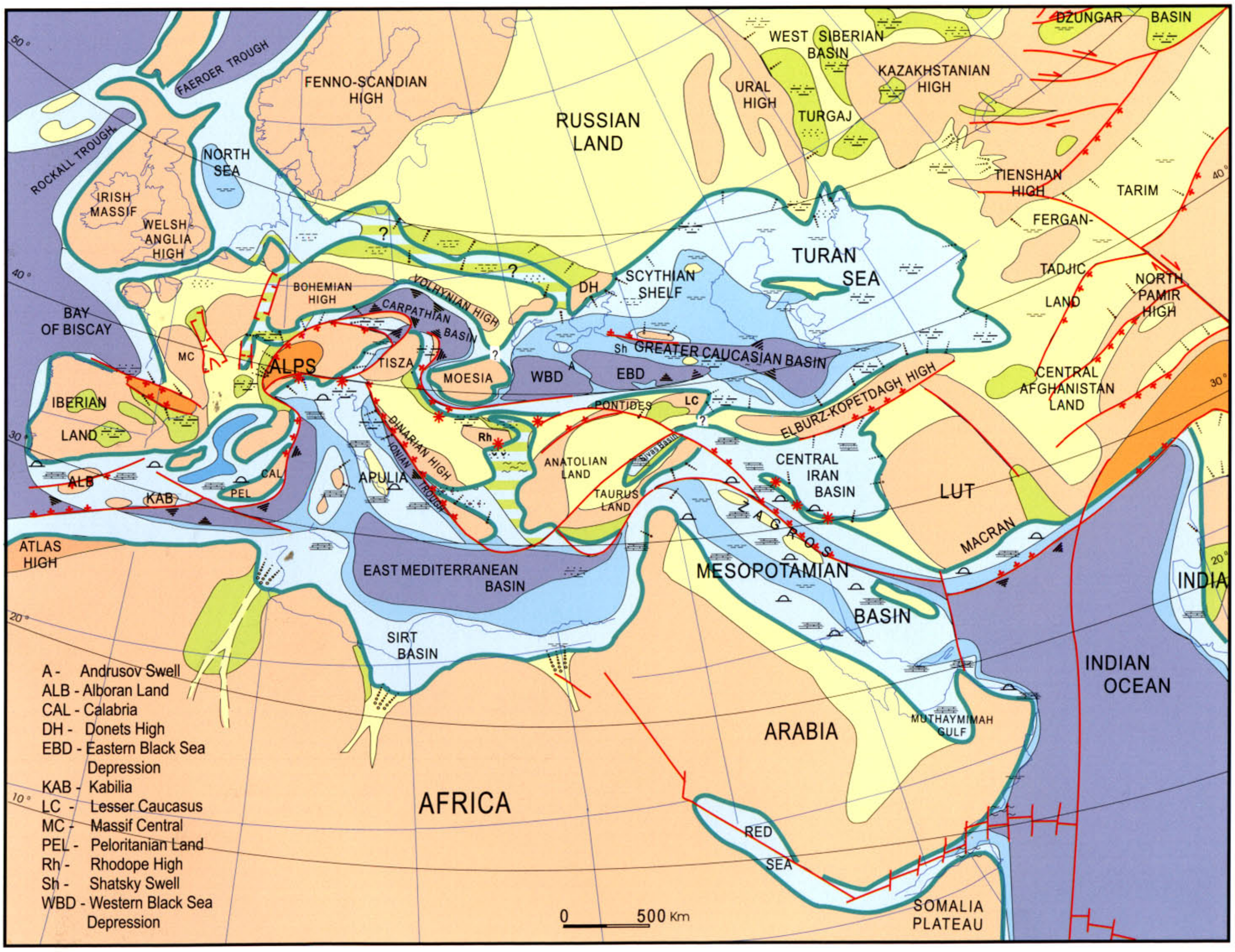
Compiled by: S.V. Popov, I.G. Shcherba, A.S. Stolyarov

Map **3**

Co-authors: K. Gürs, M. Kovac, V.A. Krasheninnikov,
A. Nagymarosy, B.I. Pinkhasov, F. Rögl, A. Rusu

Late Oligocene

29 - 24 Ma



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Map 3. Late Oligocene *(CHATTIAN - EGERIAN - KALMYKIAN)*

Legend

I. LITHOLOGY:

- *Breccia*
- *Conglomerate*
- *Sand and sandstone*
- *Silt and siltstone*
- *Clay*
- *Anoxic clay*
- *Marl*
- *Limestone*
- *Silicilith*
- *Intrusive massif*
- *Acidic extrusives*
- *Terrigenious flysch*
- *Anhydrite and gypsum*
- *Ashes and tuff material*

II. MINERAL RESOURCES

- *Coal*
- *Oil and gas*
- Mn *Manganese*
- U *Uranium and rare earth*
- *Ferruginous*

III. PALEOGEOGRAPHY

Marine environments:

- *Shallow shelf*
- *Deep shelf*
- *Deep shelfal depression*
- *Continental slope and basin bottom*
- *Brackish environments*

Continental environments:

- *Freshwater lake, marshes*
- *Lowlands*
- *Highlands*
- *Mountain*
- a, b *Boundary of different paleogeographic conditions*
  a - established, b - inferred
- *Lithofacies boundary*
- *Boundary of recent extension of deposits*
- *Sea - continent transition*
- *Bioherm*
- *Delta, fans*
- *Turbidites*
- *Volcanoes*
- *Sediment source*
- ·75 *Thickness in section*
- 10 *Isopachits*
- *Synsedimental fault and flexures:*
- a, b *Overthrusts: a - synsedimentary, b - postsedimentary*
- *Transcurrent faults:*
  a - synsedimentary, b - postsedimentary

<u>Published and unpublished materials were used:</u>

Andjelkovic et al. 1991; Baldi 1986; Balla 1984; Barthelt et. al. 1988; Beer & Shcherba 1984; Berger 1996; Chekunov et al. 1976; Csontos et al. 1992; Dercourt et al. 1985; Dercourt et al. 1993; Dercourt et al. 2000; Frisch et al. 1998; Furrer & Soder 1955; Gansser 1957; Goff et al. 1995; Jiricek & Seifert 1990; Jones & Racey 1994; Karasev 1948; Kopp & Shcherba 1998; Kovac et al. 2002; Kunin et al. 1989, 1990; Lüttig & Steffens 1976; Nagymarosy 1990; Nagymarosy & Baldi-Beke1993; Neogene paleog. Atlas of Central and E. Europe 1988; Poisson et al. 1997; Ponikarov et al. 1968 ; Rögl 1998; Rögl & Steininger 1983; Saidov & Kuschanin 1947; Sandulescu & Micu 1988; Shcherba 1993; Sissingh 1997, 1998; Steininger & Wessely 2000; Stolyarov 1991; Tugolesov et al. 1985; Vinogradov 1967-1969; Wagner 1996; Yetis et al. 1995; Ziegler 1990.

Sponsored by Peri-Tethys Programme, Grant 25 and Hans Rausing Fond.

Map 3: Late Oligocene (Chattian Egerian Kalmykian). In: Popov, S.V., Rögl, F., Rozanov, A.Yu., Steininger, F.F., Shcherba, I.G. & Kovac, M. (2004): Lithological-Paleogeographic maps of Paratethys. Courier Forschungsinstitut Senckenberg, 250: 1-46; maps 1-10.

Lithological-Paleogeographic maps of Paratethys

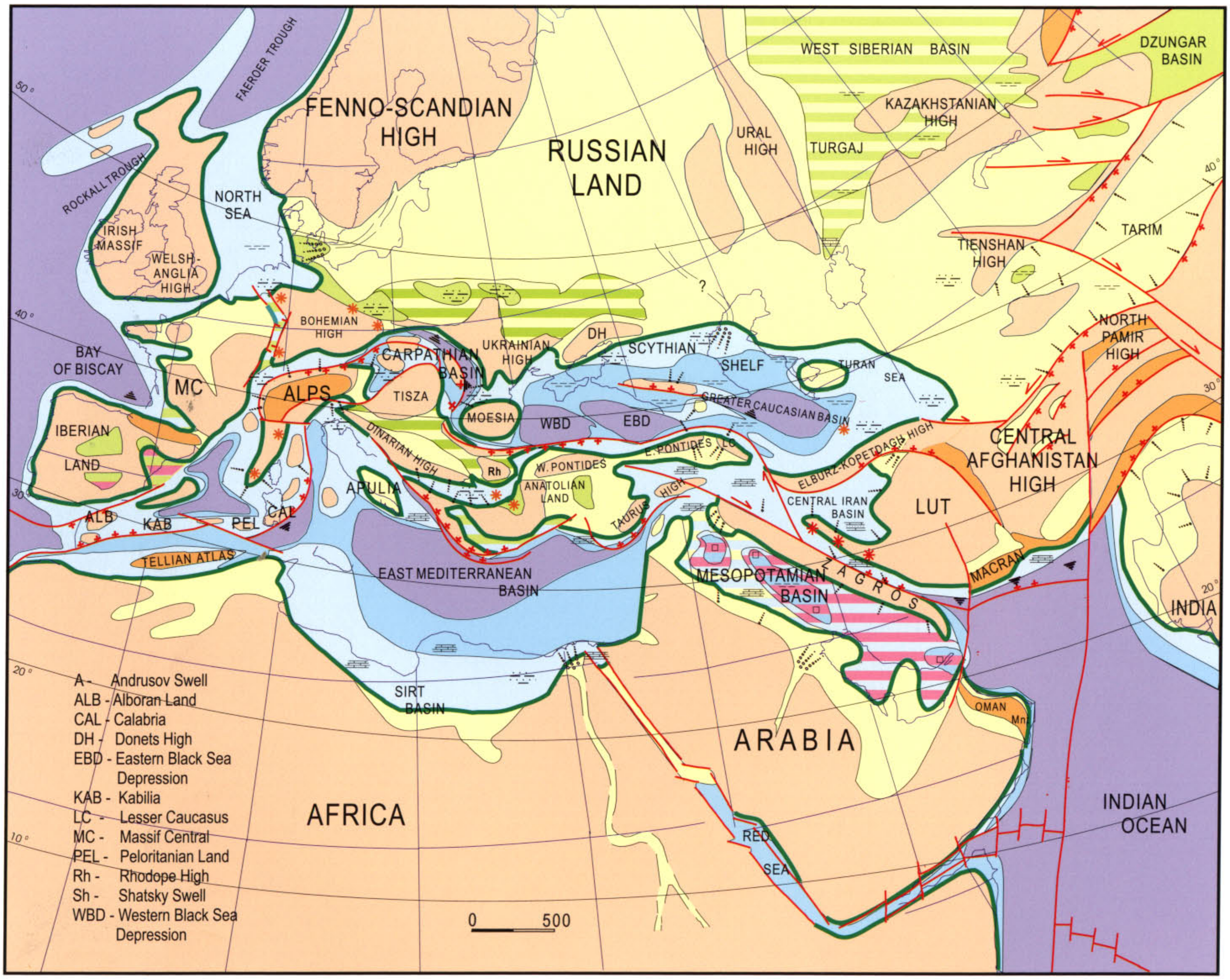
Compiled by: S.V. Popov, I.G. Shcherba, A.S. Stolyarov

Co-authors: K. Gürs, M. Kovac, V.A. Krasheninnikov,
A. Nagymarosy, B.I. Pinkhasov, F. Rögl, A. Rusu

Map 4

Early Miocene

20,5-19 Ma



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Map 4. Early Miocene *(BURDIGALIAN, EGGENBURGIAN, SAKARAULIAN)*

Legend

I. LITHOLOGY:

- *Breccia*
- *Conglomerate*
- *Sand and sandstone*
- *Silt and siltstone*
- *Clay*
- *Anoxic clay*
- *Marl*
- *Limestone*
- *Silicilith*
- *Intrusive massif*
- *Basic and intermediate volcanics*
- *Terrigenous flysch*
- *Anhydrite and gypsum*

II. MINERAL RESOURCES

- *Coal*
- *Oil and gas*
- Mn *Manganese*
- *Chloritic salts*

III. PALEOGEOGRAPHY

Marine environments:

- *Shallow shelf*
- *Deep shelf*
- *Deep shelfal depression*
- *Continental slope, basin bottom*

Continental environments:

- *Freshwater lake, marsh*
- *Lowland*
- *Highland*
- *Mountain range*
- a, b *Paleogeographic boundary, a - established, b - inferred*
- *Lithofacies boundary*
- *Present-day limit of deposits*
- *Sea - continent transition*
- *Bioherm*
- *Delta, pro-delta, fan*
- *Turbidites*
- *Volcano*
- *Sediment supply*
- ·75 · (650) *Thickness in meters , established and aproximate*
- 10 *Isopach in meters*
- *Syn-sedimentary fault, flexure*
- a, b *Overthrust: a - synsedimentary, b - postsedimentary*
- a, b *Strike-slip fault: a - synsedimentary, b - postsedimentary*

<u>Published and unpublished materials were used:</u>

Andjelkovic et al. 1991; Baldi 1986; Balla 1984; Barthelt et al. 1988; Beer & Shcherba 1984; Berger 1996; Boccaletti et al. 1990; Cahuzac et al. 1992; Chekunov et al. 1976; Csontos et al. 1992; Dercourt et al. 1985; Dercourt et al. 1993; Dercourt et al. 2000; Erentoz 1956; Frisch et al. 1998; Furrer & Soder 1955; Gansser 1957; Goff et al. 1995; Jiricek & Seifert 1990; Jones & Racey 1994; Karasev 1948; Kopp & Shcherba 1998; Kovac et al. 1989; Kovac 2000; Kunin et al. 1989, 1990; Lüttig & Steffens 1976; Nagymarosy 1990; Nagymarosy & Baldi-Beke 1993; Ozsayar 1977; Poisson et al. 1997; Ponikarov et al. 1968; Rögl 1998; Rögl & Steininger 1983; Saidov & Kuschanin 1947; Sandulescu & Micu 1988; Seifert et al. 1991; Shcherba 1993; Sissingh 2001; Steininger et al. 1985; Steininger & Wessely 2000; Stolyarov 1991; Tugolesov et al. 1985; Vinogradov 1967-1969; Wagner 1996; Yetis et al. 1995; Ziegler 1990.

Map 4: Early Miocene (Burdigalian, Eggenburgian, Sakaraulian). In: Popov, S.V., Rögl, F., Rozanov, A.Yu., Steininger, F.F., Shcherba, I.G. & Kovac, M. (2004): Lithological-Paleogeographic maps of Paratethys. Courier Forschungsinstitut Senckenberg, 250: 1-46; maps 1-10.

Lithological-Paleogeographic maps of Paratethys

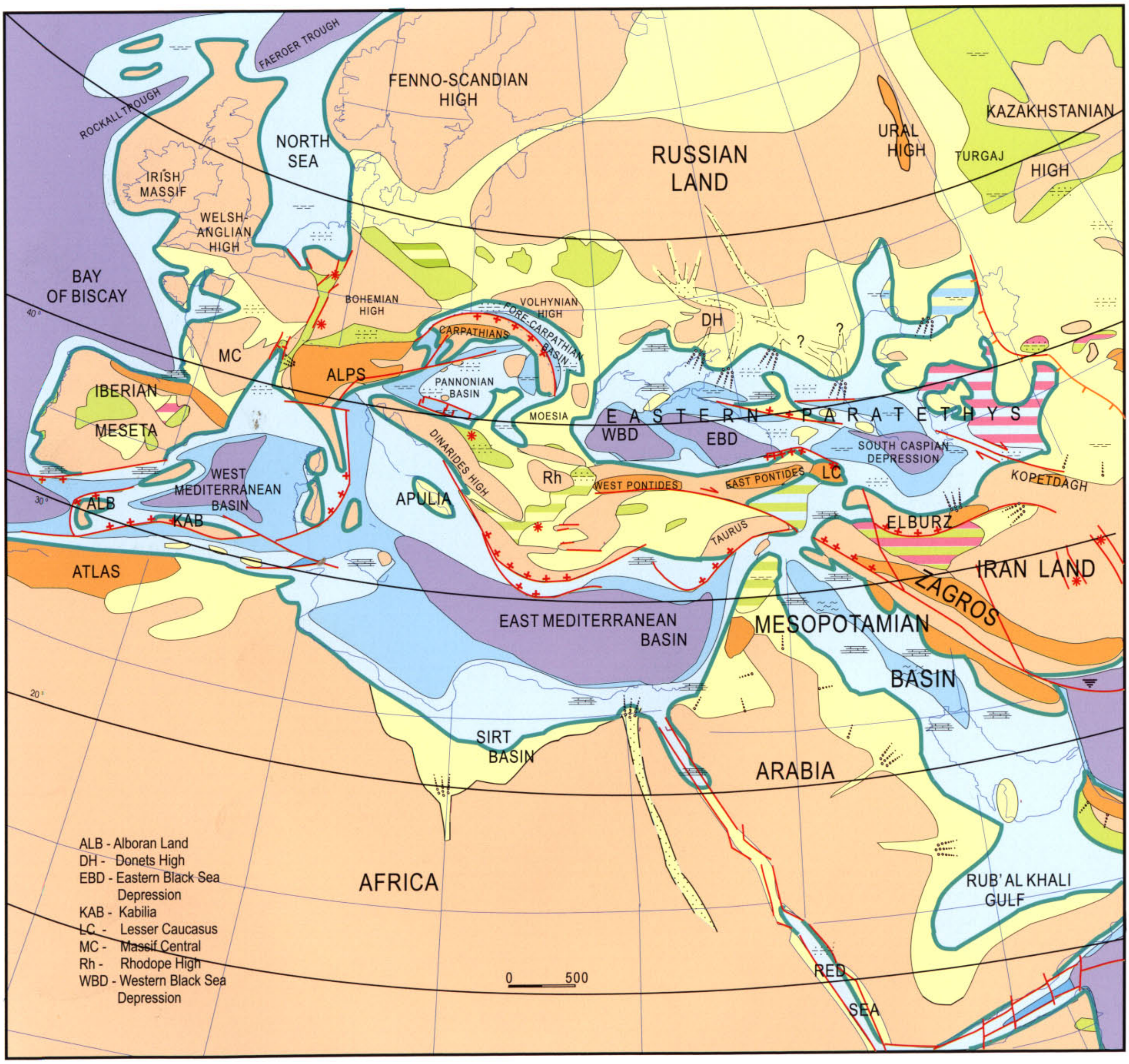
Compiled by: I.A. Goncharova, I.G. Shcherba, S.O. Khondkarian

Co-authors: K. Gürs, Ju.I. Iosifova, T.V. Jakubovskaja, M. Kovac, V.A. Krasheninnikov, T.N. Pinchuk, B.I. Pinkhasov, S.V. Popov, G. Popescu, F. Rögl, A. Rusu, A.V. Zajtsev, A.S. Zastrozhnov

Map 5

Early Middle Miocene

16 - 15 Ma



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Map 5. Early Middle Miocene *(LANGHIAN, Early BADENIAN, CHOKRAKIAN)*

Legend

I. LITHOLOGY:

Breccia
Conglomerate
Sand and sandstone
Silt and siltstone
Clay
Anoxic clay
Marl
Limestone
Diatomite
Intrusive massif
Basic volcanics
Acidic volcanics
Terrigenous flysch
Anhydrite and gypsum

II. MINERAL RESOURCES

Coal
Oil and gas
Chloritic salts

III. PALEOGEOGRAPHY

Marine environments:

Shallow shelf
Deep shelf
Deep shelfal depression
Continental slope, basin bottom

Continental environments:

Freshwater lake, marsh
Lowland
Highland
Mountain range
Paleogeographic boundary, a - established, b - inferred
Lithofacies boundary
Present-day limit of deposits
Sea - continent transition
River valley
Bioherm
Delta, pro-delta, fan
Turbidites
Volcano
Sediment supply
75 (650) *Thickness in meters, established and aproximate*
10 *Isopach in meters*
Synsedimentary fault, flexure
Overthrust: a - synsedimentary, b - postsedimentary
Strike-slip fault: a - synsedimentary, b - postsedimentary

Published and unpublished materials were used:

Ali-Zade et al. 1980; Andjelkovic et al. 1991; Barthelt 1988; Berger 1996; Boccaletti et al. 1990; Bondarchuk et al. 1960; Cahuzac et al. 1992; Chekunov et al. 1976; Csontos et al. 1992; Ctyroky et al. 1975; Dercourt et al. 1985; Dercourt et al. 1993; Dercourt et al. 2000; Devjatkin et al. 2000; Dumurdzanov & Krstic 1999; Erentoz 1956; Frisch et al. 1998; Furrer & Soder 1955; Gansser 1957; Goff et al. 1995; Goncharova 1989; Goncharova et al. 2001, 2002; Karasev 1948; Kopp & Shcherba 1985, 1998; Kovac et al. 1989; Krasheninnikov 1971, 1985; Kunin et al. 1989, 1990; Lüttig & Steffens 1976; Nagymarosy 1990; Pinkhasov 1984; Poisson et al. 1997; Ponikarov et al. 1968; Radoicic et al. 1991; Robinson 1995; Rögl 1998; Rögl & Steininger 1983; Saidov & Kuschanin 1947; Seifert et al. 1991; Shcherba 1993; Sissingh 1997, 1998; Steininger et al. 1985; Steininger & Wessely 2000; Tugolesov et al. 1985; Vinogradov 1967-1969; Wagner 1996; Yetis et al. 1995; Ziegler 1990.

Map 5: Early Middle Miocene (Langhian, Early Badenian Chokrakian). In: Popov, S.V., Rögl, F., Rozanov, A.Yu., Steininger, F.F., Shcherba, I.G. & Kovac, M. (2004): Lithological-Paleogeographic maps of Paratethys. Courier Forschungsinstitut Senckenberg, 250: 1-46; maps 1-10.

Lithological-Paleogeographic maps of Paratethys

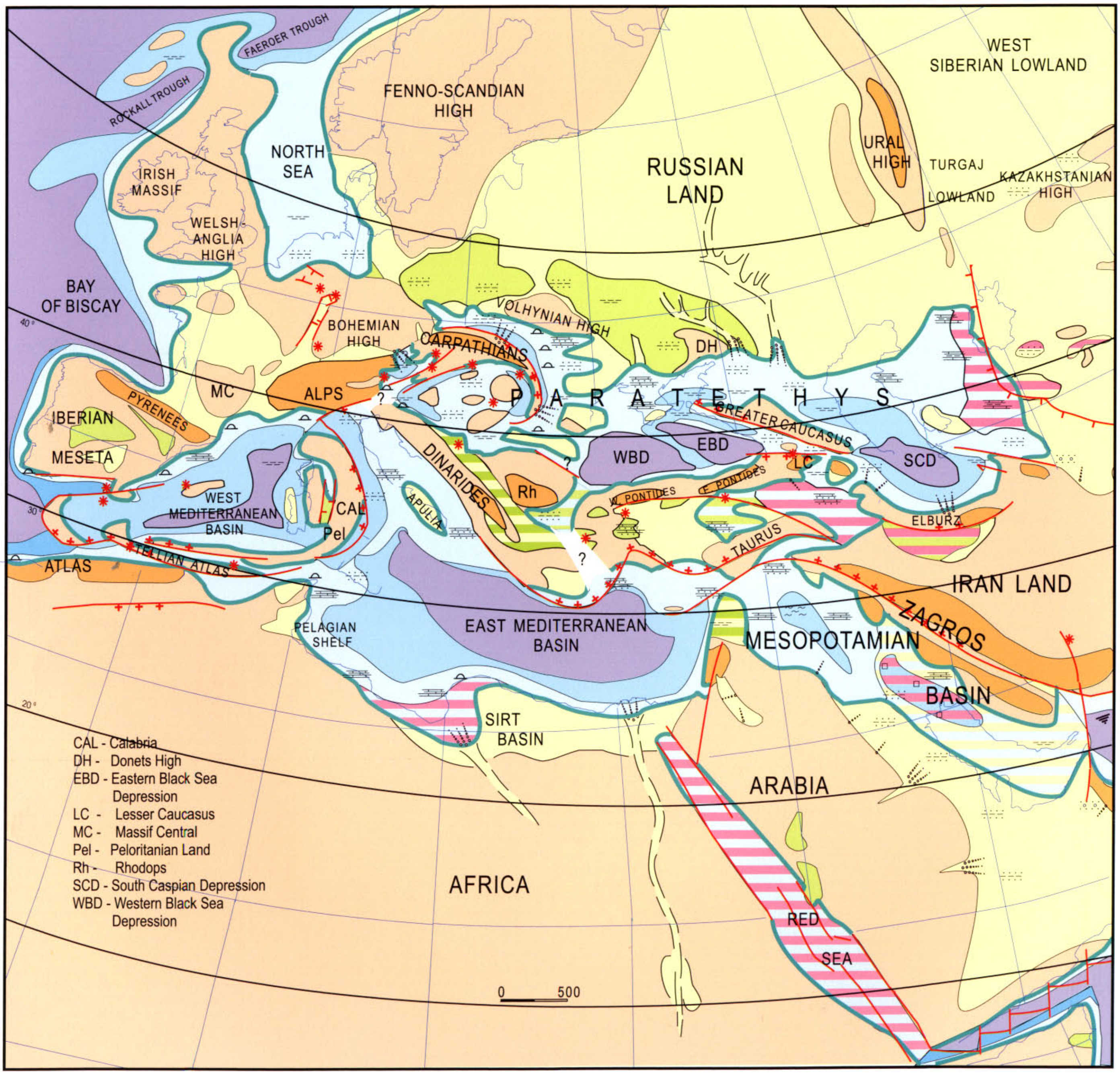
Compiled by: L.B. Ilyina, I.G. Shcherba,
S.O. Khondkarian, I.A. Goncharova

Co-authors: K. Gürs, Ju.I. Iosifova,
T.V. Jakubovskaja, M. Kovac, V.A. Krasheninnikov,
A. Nagymarosy, T.N. Pinchuk, S.V. Popov,
G. Popescu, A. Rusu

Map 6

Mid Middle Miocene

14 -13 Ma



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Map 6. Mid Middle Miocene *(Middle SERRAVALLIAN, Late BADENIAN, KONKIAN)*

Legend

I. LITHOLOGY:

- *Conglomerate*
- *Sand and sandstone*
- *Silt and siltstone*
- *Clay*
- *Marl*
- *Limestone*
- *Intrusive massif*
- *Basic volcanics*
- *Acidic volcanics*
- *Anhydrite and gypsum*
- *Coal*
- *Chloritic salts*

II. PALEOGEOGRAPHY

Marine environments:

- *Shallow shelf*
- *Deep shelf*
- *Deep shelfal depression*
- *Continental slope, basin bottom*

Continental environments:

- *Freshwater lake, marsh*
- *Lowland*
- *Highland*
- *Mountain range*

- a, b — *Paleogeographic boundary, a - established, b - inferred*
- *Lithofacies boundary*
- *Present-day limit of deposits*
- *Sea - continent transition*
- *River valley*
- *Bioherm*
- *Delta, pro-delta, fan*
- *Turbidites*
- *Volcano*
- *Sediment supply*
- .75 . (650) — *Thickness in meters, established and aproximate*
- 10 — *Isopach in meters*
- *Synsedimentary fault, flexure*
- a, b — *Overthrust: a - synsedimentary, b - postsedimentary*
- a, b — *Strike-slip fault: a - synsedimentary, b - postsedimentary*

<u>Published and unpublished materials were used:</u>

Ali-Zade et al. 1980; Andjelkovic et al. 1991; Barthelt 1988; Boccaletti et al. 1990; Cahuzac et al. 1992; Chekunov et al. 1976; Csontos et al. 1992; Dercourt et al. 1985; Dercourt et al. 1993; Dercourt et al. 2000; Dumurdzanov & Krstic 1999; Erentoz 1956; Gansser 1957; Gelati 1975; Goff et al. 1995; Goncharova & Ilyina 1997; Goncharova & Shcherba 1977; Ilyiana 2000; Karasev 1948; Kojumdgieva & Strashimirov 1960; Kolesnikov 1936; Kopp & Shcherba 1998; Kovac et al. 1989; Kulichenko & Savron 1984, Lüttig & Steffens 1976; Muratov & Nevesskaya 1986; Öszayar 1977; Ponikarov et al. 1968; Radoicic et al. 1991; Robinson 1995; Rögl 1998; Rögl & Steininger 1983; Saidov & Kuschanin 1947; Seifert et al. 1991; Shcherba 1993; Sissingh 1997, 1998; Steininger et al. 1985; Steininger & Wessely 2000; Tugolesov et al. 1985; Vinogradov 1967-1969; Yetis et al. 1995; Ziegler 1990.

Map 6: Mid Middle Miocene (Middle Serravallian, Late Badenian, Konkian). In: Popov, S.V., Rögl, F., Rozanov, A.Yu., Steininger, Shcherba, I.G. & Kovac, M. (2004): Lithological-Paleogeographic maps of Paratethys. Courier Forschungsinstitut Senckenberg, 250: 1-46; maps 1-10.

Lithological-Paleogeographic maps of Paratethys

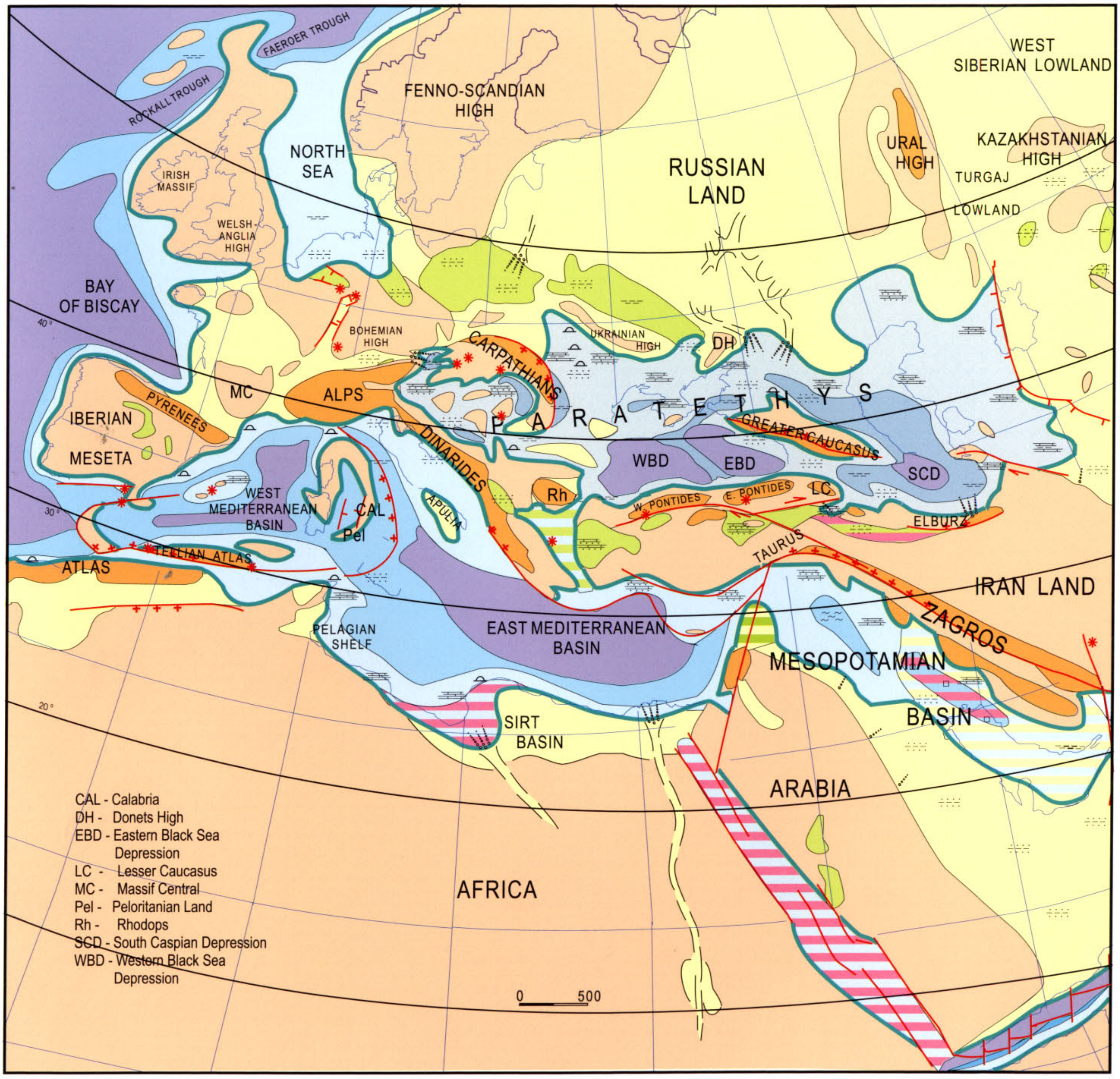
Compiled by: N.P. Paramonova, I.G. Shcherba, S.O. Khondkarian

Co-authors: K. Gürs, Ju.I. Iosifova,
T.V. Jakubovskaja, M. Kovac, I. Magyar,
T.N. Pinchuk, S.V. Popov, A.S. Zastrozhnov

Map 7

Late Middle Miocene

12 -11 Ma



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Map 7. Late Middle Miocene *(Late SERRAVALLIAN, SARMATIAN s.s., Middle SARMATIAN s.l.)*

Legend

I. LITHOLOGY:

- *Breccia*
- *Conglomerate*
- *Sand and sandstone*
- *Silt and siltstone*
- *Clay*
- *Marl*
- *Limestone*
- *Diatomite*
- *Intrusive massif*
- *Basic volcanics*
- *Acidic volcanics*
- *Anhydrite and gypsum*
- *Coal*
- *Chloritic salts*

II. PALEOGEOGRAPHY

Marine environments:

- *Shallow shelf*
- *Deep shelf*
- *Deep shelfal depression*
- *Continental slope, basin bottom*

Semi-marine environments:

- *Shallow shelf*
- *Deep shelf*
- *Continental slope, basin bottom*

Continental environments:

- *Freshwater lake, marsh*
- *Lowland*
- *Highland*
- *Mountain range*

- a, b — *Paleogeographic boundary, a - established, b - inferred*
- *Lithofacies boundary*
- *Present-day limit of deposits*
- *Sea - continent transition*
- *River valley*
- *Bioherm*
- *Delta, pro-delta, fan*
- *Volcano*
- *Sediment supply*
- -75, (650) — *Thickness in meters, established and aproximate*
- 10 — *Isopach in meters*
- *Synsedimentary fault, flexure*
- a, b — *Overthrust: a - synsedimentary, b - postsedimentary*
- a, b — *Strike-slip fault: a - synsedimentary, b - postsedimentary*

Published and unpublished materials were used:

Ali-Zade et al. 1980; Andjelkovic et al. 1991; Barthelt 1988; Boccaletti et al. 1990; Cahuzac et al. 1992; Chekunov et al. 1976; Dercourt et al. 1993; Dercourt et al. 2000; Dumurdzanov & Krstic 1999; Goff et al. 1995; Jones & Racey 1994; Karasev 1948; Kolesnikov 1936; Kovac et al. 1989; Lüttig & Steffens 1976; Muratov & Nevesskaya 1986; Öszayar 1977; Ponikarov et al. 1968; Radoicic et al. 1991; Robinson 1995; Rögl 1998; Rögl & Steininger 1983; Saidov & Kuschanin 1947; Seifert et al. 1991; Shcherba 1993; Sissingh 1997, 1998; Steininger & Wessely 2000; Tugolesov et al. 1985; Vinogradov 1967-1969; Yetis et al. 1995; Zhizhenko et al. 1968; Ziegler 1990.

Map 7: Late Middle Miocene (Late Seravallian, Sarmatian s.s., Middle Sarmatian s.l.). In: Popov, S.V., Rögl, F., Rozanov, A.Yu., Steininger, F.F., Shcherba, I.G. & Kovac, M. (2004): Lithological-Paleogeographic maps of Paratethys. Courier Forschungsinstitut Senckenberg, 250: 1-46; maps 1-10.

Lithological-Paleogeographic maps of Paratethys

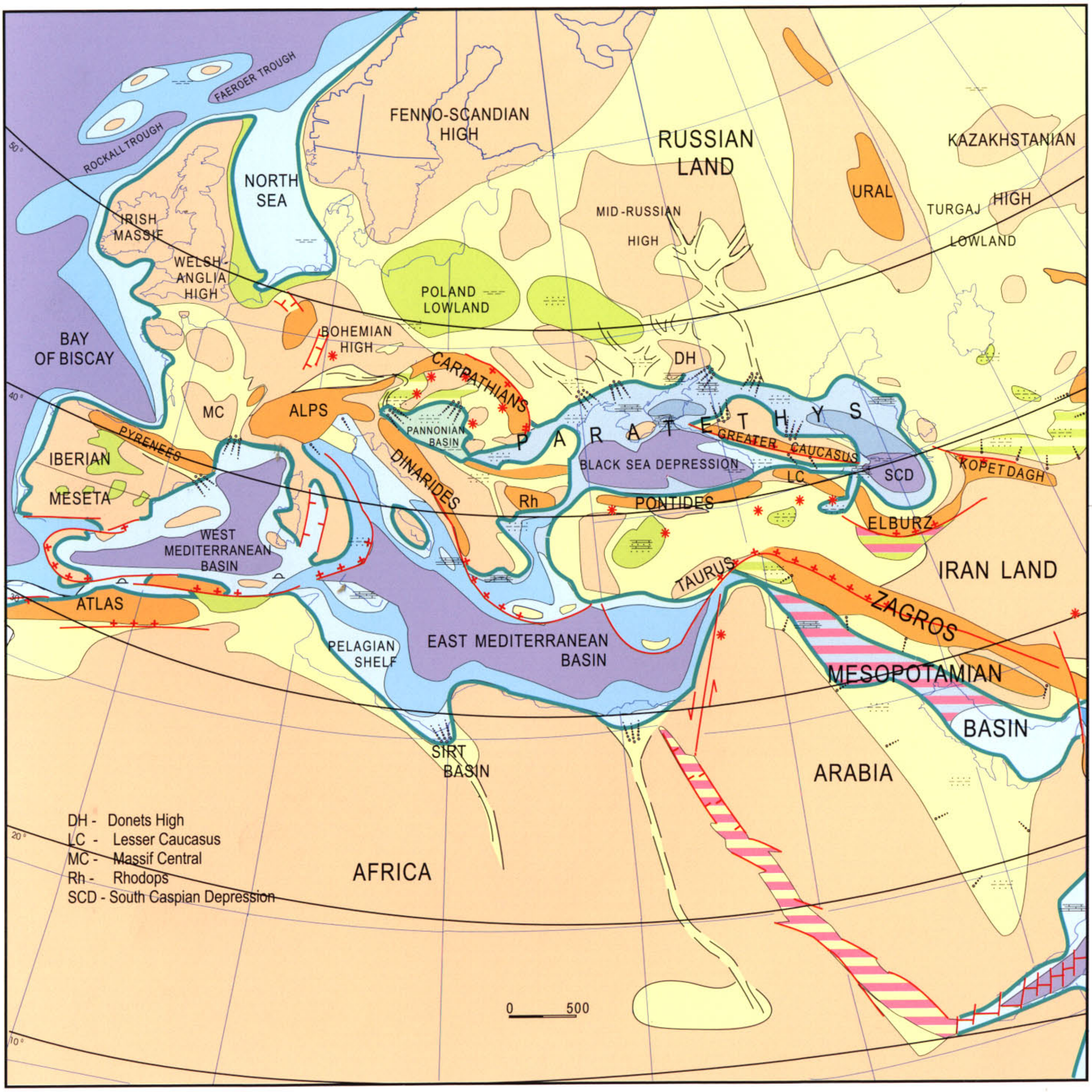
Compiled by: L.B. Ilyina, I.G. Shcherba, S.O. Khondkarian

Co-authors: K. Gürs, Ju.I. Iosifova, T.V. Jakubovskaja, M. Kovac, I. Magyar, T.N. Pinchuk, S.V. Popov

Map 8

Mid Late Miocene

8.5 - 7.0 Ma



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Map 8. Mid Late Miocene *(Late TORTONIAN - Early MESSINIAN - Early MAEOTIAN - Late PANNONIAN)*

Legend

I. LITHOLOGY:

- *Conglomerate*
- *Sand and sandstone*
- *Silt and siltstone*
- *Clay*
- *Marl*
- *Limestone*
- *Diatomite*
- *Intrusive massif*
- *Basic volcanics*
- *Acidic volcanics*
- *Anhydrite and gypsum*
- *Coal*

II. PALEOGEOGRAPHY

Marine environments:

- *Shallow shelf*
- *Deep shelf*
- *Deep shelfal depression*
- *Continental slope, basin bottom*

Semi-marine environments:

- *Shallow shelf*
- *Deep shelf*
- *Continental slope, basin bottom*

Brackish environments:

- *Shallow shelf*
- *Deep shelfal depression*

Continental environments:

- *Freshwater lake, marsh*
- *Lowland*
- *Highland*
- *Mountain range*

- a b *Paleogeographic boundary, a - established, b - inferred*
- *Lithofacies boundary*
- *Present-day limit of deposits*
- *Sea - continent transition*
- *River valley*
- *Bioherm*
- *Delta, pro-delta, fan*
- *Volcano*
- *Sediment supply*
- 75 (650) *Thickness in meters, established and aproximate*
- 10 *Isopach in meters*
- *Synsedimentary fault, flexure*
- a b *Overthrust: a - synsedimentary, b - postsedimentary*
- a b *Strike-slip fault: a - synsedimentary, b - postsedimentary*

Published and unpublished materials were used:

Ali-Zade et al. 1980; Andjelkovic et al. 1991; Barthelt 1988; Boccaletti et al. 1990; Cahuzac et al. 1992; Chekunov et al. 1976; Dercourt et al. 1993; Dercourt et al. 2000; Dumurdzanov & Krstic 1999; Goff et al. 1995; Karasev 1948; Kovac et al. 1989; Lüttig & Steffens 1976; Magyar et al. 1999; Muratov & Nevesskaya 1986; Öszayar 1977; Ponikarov et al. 1968; Robinson 1995; Rögl 1998; Rögl & Steininger 1983; Saidov & Kuschanin 1947; Seifert et al. 1991; Shcherba 1993; Shcherba et al. 2001; Sissingh 1997, 1998; Steininger et al. 1985; Steininger & Wessely 2000; Tugolesov et al. 1985; Vinogradov 1967-1969; Yetis et al. 1995; Ziegler 1990.

Map 8: Mid Late Miocene (Late Tortonian Early Messinian - Early Maeotian Late Pannonian). In: Popov, S.V., Rögl, F., Rozanov, A.Yu., Steininger, F.F., Shcherba, I.G. & Kovac, M. (2004): Lithological-Paleogeographic maps of Paratethys. Courier Forschungsinstitut Senckenberg, 250: 1-46; maps 1-10.

Lithological-Paleogeographic maps of Paratethys

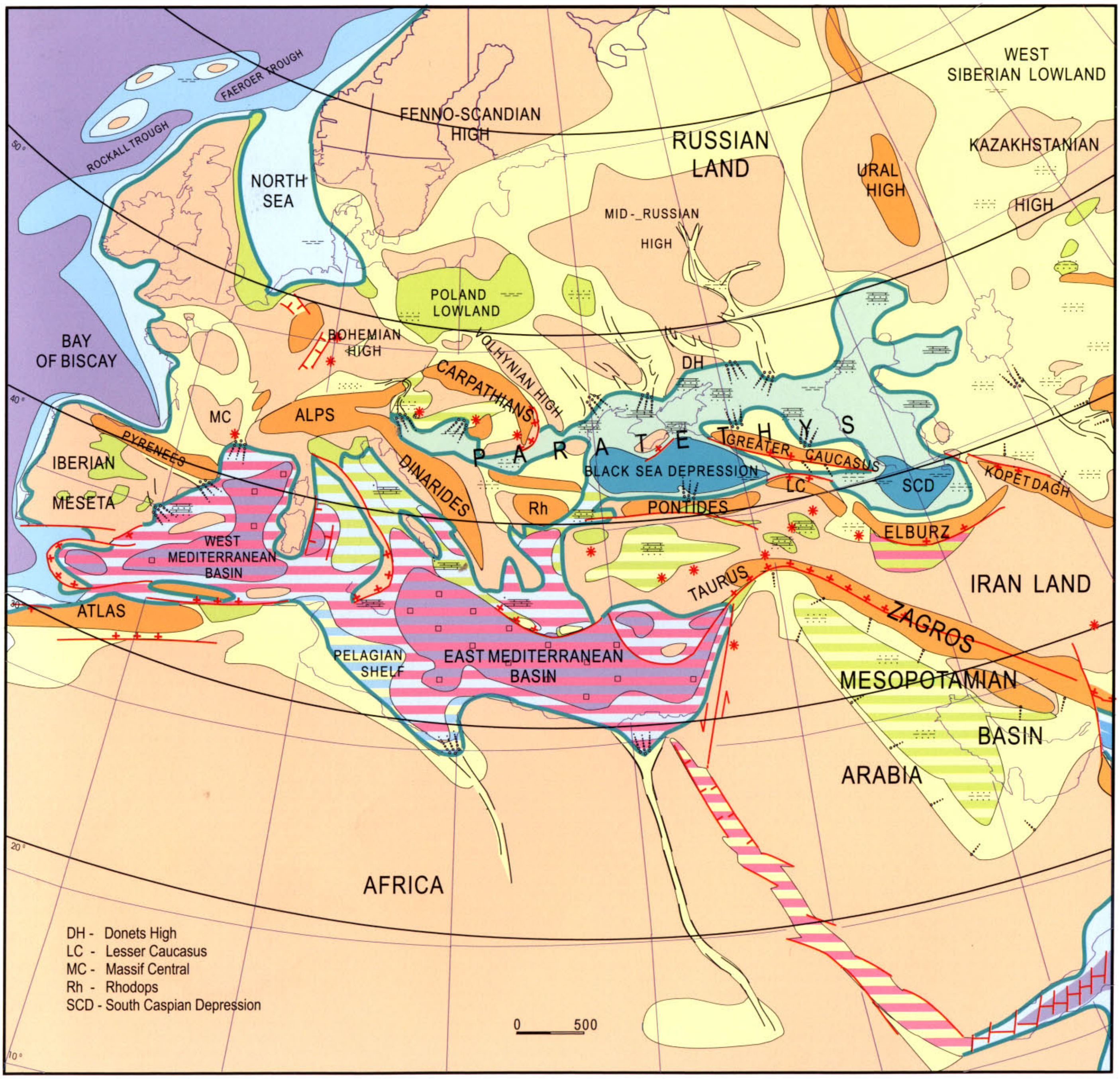
Compiled by: S.O. Khondkarian, I.G. Shcherba, S.V. Popov

Co-authors: K. Gürs, Ju.I. Iosifova,
T.V. Jakubovskaja, M. Kovac, I. Magyar,
T.N. Pinchuk, A.S. Zastrozhnov

Map 9

Latest Miocene

6,1 - 5,7 Ma



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Map 9. Latest Miocene *(Late MESSINIAN, Early PONTIAN-Late PANNONIAN)*

Legend

I. LITHOLOGY:

Breccia

Conglomerate

Sand and sandstone

Silt and siltstone

Clay

Marl

Limestone

Intrusive massif

Basic volcanics

Acidic volcanics

Anhydrite and gypsum

Coal

Chloritic salts

II. PALEOGEOGRAPHY

Marine environments:

Shallow shelf

Deep shelf

Deep shelfal depression

Continental slope, basin bottom

Brackish environments:

Shallow shelf

Deep shelfal depression

Continental environments:

Freshwater lake, marsh

Lowland

Highland

Mountain range

Paleogeographic boundary, a - *established,* b - *inferred*

Lithofacies boundary

Present-day limit of deposits

Sea - continent transition

River valley

Bioherm

Delta, pro-delta, fan

Volcano

Sediment supply

Thickness in meters , established and aproximate (75, (650))

Isopach in meters (10)

Synsedimentary fault, flexure

Overthrust: a - *synsedimentary,* b - *postsedimentary*

Strike-slip fault: a - *synsedimentary,* b - *postsedimentary*

Published and unpublished materials were used:

Andjelkovic et al. 1991; Barthelt 1988; Boccaletti et al. 1990; Cahuzac et al. 1992; Chekunov et al. 1976; Dercourt et al. 1993; Dercourt et al. 2000; Dumurdzanov & Krstic 1999; Goff et al. 1995; Jones & Racey 1994; Lüttig & Steffens 1976; Magyar et al. 1999; Öszayar 1977; Ponikarov et al. 1968; Robinson 1995; Rögl 1998; Rögl & Steininger 1983; Saidov & Kuschanin 1947; Shcherba 1993; Sissingh 1997, 1998; Steininger & Wessely 2000; Tugolesov et al. 1985; Vinogradov 1967-1969; Yetis et al. 1995; Ziegler 1990.

Map 9: Latest Miocene (Late Messinian, Early Pontian Late Pannonian). In: Popov, S.V., Rögl, F., Rozanov, A.Yu., Steininger, F.F., Shcherba, I.G. & Kovac, M. (2004): Lithological-Paleogeographic maps of Paratethys. Courier Forschungsinstitut Senckenberg, 250: 1-46; maps 1-10.

Lithological-Paleogeographic maps of Paratethys

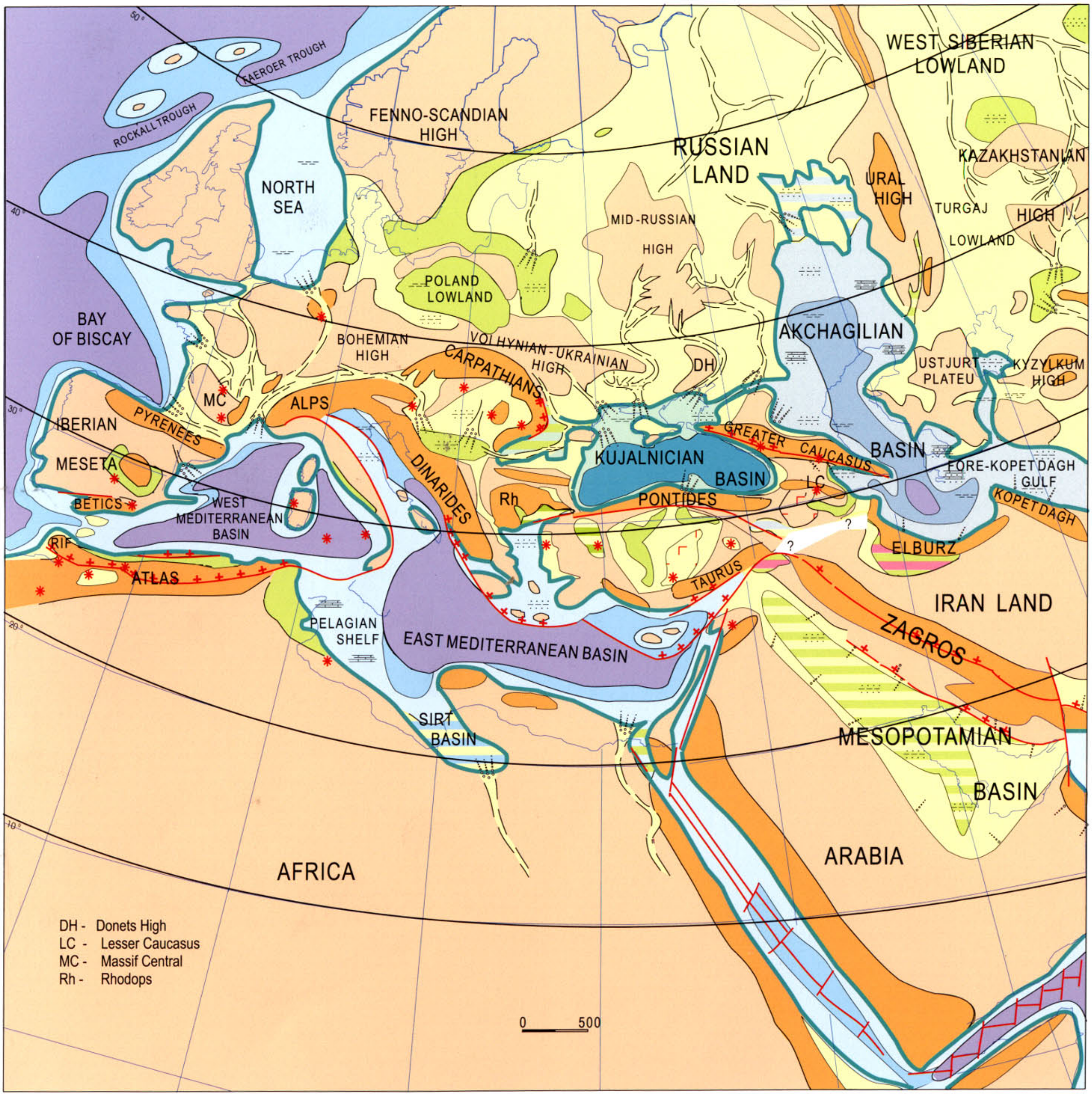
Compiled by: S.O.Khondkarian, N.P. Paramonova, I.G. Shcherba

Co-authors: K. Gürs, Ju.I. Iosifova,
T.V. Jakubovskaja, M. Kovac,
I. Magyar, T.N. Pinchuk,
S.V. Popov, A.S. Zastrozhnov

Map 10

Middle - Late Pliocene

3,4 - 1,8 Ma



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Map 10. Middle - Late Pliocene *(PIACENTIAN - GELASIAN, Late ROMANIAN - AKCHAGILIAN)*

Legend

I. LITHOLOGY:

Conglomerate

Sand and sandstone

Silt and siltstone

Clay

Marl

Limestone

Intrusive massif

Basic volcanics

Acidic volcanics

Anhydrite and gypsum

Coal

II. PALEOGEOGRAPHY

Marine environments:

Shallow shelf

Deep shelf

Deep shelfal depression

Continental slope and basin bottom

Semi-marine environments:

Shallow shelf

Deep shelf

Continental slope and basin bottom

Brackish environments:

Shallow shelf

Deep shelfal depression

Continental environments:

Freshwater lake, marsh

Lowland

Highland

Mountain range

a b *Paleogeographic boundary, a - established, b - inferred*

Lithofacies boundary

Present-day limit of deposits

Sea - continent transition

River valley

Bioherm

Delta, pro-delta, fan

Volcano

Sediment supply

·75 ·(650) *Thickness in meters , established and aproximate*

10 *Isopach in meters*

Synsedimentary fault, flexure

a b *Overthrust: a - synsedimentary, b - postsedimentary*

a b *Strike-slip fault: a - synsedimentary, b - postsedimentary*

<u>Published and unpublished materials were used:</u>

Andjelkovic et al. 1991; Barthelt 1988; Boccaletti et al. 1990; Cahuzac et al. 1992; Chekunov et al. 1976; Chepalyga 1995; Dercourt et al. 1993; Dercourt et al. 2000; Goff et al. 1995; Jones & Racey 1994; Karasev 1948; Lüttig & Steffens 1976; Magyar et al. 1999; Öszayar 1977; Ponikarov et al. 1968; Robinson 1995; Rögl 1998; Rögl & Steininger 1983; Saidov & Kuschanin 1947; Shcherba 1993; Sissingh 1997, 1998; Steininger & Wessely 2000; Tugolesov et al. 1985; Vinogradov 1967-1969; Yetis et al. 1995; Ziegler 1990.

Map 10: Middle-Late Pliocene (Piacentian Gelasian, Late Romanian, Akchagilian). In: Popov, S.V., Rögl, F., Rozanov, A.Yu., Steininger, F.F., Shcherba, I.G. & Kovac, M. (2004): Lithological-Paleogeographic maps of Paratethys. Courier Forschungsinstitut Senckenberg, 250: 1-46; maps 1-10.

Map 1. Late Eocene *(PRIABONIAN - BELOGLINIAN)*

SCALE 1 : 7 500 000

75 0 75 150 225 300 375

Map 2. Early Oligocene *(Early RUPELIAN, Early KISCELLIAN - PSCHEKHIAN)*

SCALE 1: 7 500 000

75 0 75 150 225 300 375

Map 3. Late Oligocene (*CHATTIAN - EGERIAN - KALMYKIAN*)

SCALE 1 : 7 500 000

75 0 75 150 225 300 375

Map 4. Early Miocene *(BURDIGALIAN, EGGENBURGIAN, SAKARAULIAN)*

SCALE 1 : 7 500 000

75 0 75 150 225 300 375

Map 5. Early Middle Miocene (*LANGHIAN, Early BADENIAN, CHOKRAKIAN*)

SCALE 1 : 7 500 000

75 0 75 150 225 300 375

Map 6. Mid Middle Miocene (*Middle SERRAVALLIAN, Late BADENIAN, KONKIAN*)

Map 7. Late-Middle Miocene (*Late SERRAVALLIAN, SARMATIAN s.s., Middle SARMATIAN s.l.*)

Map 8. Mid Late Miocene (*Late TORTONIAN - Early MESSINIAN - Early MAEOTIAN - Late PANNONIAN*)

Map 9. Latest Miocene *(Late MESSINIAN, Early PONTIAN - Late PANNONIAN)*

SCALE 1 : 7 500 000

Map 10. Middle - Late Pliocene *(PIACENTIAN, GELASIAN, Late ROMANIAN – AKCHAGILIAN)*

SCALE 1 : 7 500 000